*Volume 22, number 1*

*FEBRUARY, 1955*

**COVER PICTURE**

*The Rapid Transit Subway, Toronto, for which the signalling was installed by The Siemens and General Electric Railway Signal Company Ltd.*

# G.E.C. JOURNAL

## CONTENTS


| Page | | |
|---|---|---|
| 2 | Frontispiece—The Lord Mayor's Banquet, Guildhall, London, 1954 | |
| | PROGRESS 1954 | |
| 3 | Power Equipment | |
| 18 | Mining Equipment | |
| 21 | Mechanical Engineering | |
| 25 | Coal Preparation Plant | |
| 27 | Rolling Mills | |
| 29 | Industrial Electrification | |
| 33 | Transport | |
| 38 | Electronic Control | |
| 39 | Plastics | |
| 40 | Industrial and Process Heating Equipment | |
| 44 | Domestic Equipment and Household Appliances | |
| 45 | Instruments | |
| 48 | Lamps and Lighting | |
| 56 | Telecommunications | |
| 62 | Research | |
| 67 | Technical Literature | |


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*The Lord Mayor's Banquet, Guildhall, London, 1954.*
*The Guildhall was damaged by enemy action in December, 1940, and was restored by Sir Giles Gilbert Scott, O.M., R.A., P.P.R.I.B.A., who designed the new lighting fittings which the G.E.C. supplied.*

# Progress 1954

## Power Equipment

**STEAM TURBO-GENERATORS.**

The total capacity of plant commissioned for the British Electricity Authority during 1954 has exceeded that in any previous year. Included in this total are three 60 MW hydrogen-cooled sets, two at Uskmouth where four of the six sets are now in service (fig. 1), and one at Ince Power Station. Both the 30 MW sets in the Doncaster Station (fig. 2) are now in service as well as the first set for Huddersfield, where a second set of this rating has been delivered.

Generating plant delivered overseas includes three 30 MW sets for the Orlando Power Station, Johannesburg, extensions to which will bring its capacity up to 337·5 MW. For the Bloemfontein Municipality two 10 MW sets are now on site, as is also a 5 MW set for the Demerara Electric Company, British Guiana.

Orders for industrial plant to provide process steam cover three pass-out turbo-alternators for Empire, Donside and Westfield Paper Mills, a further pass-out back-pressure set for the Steel Company of Wales, and a back-pressure set for the National Physical Laboratory, Teddington. A contract has also been received for a back-pressure set for a sugar mill in British Guiana, where five sets of this type have already been delivered. The demand for marine turbo-generator sets continues ; over fifty such sets are on order and ten have been completed during the year. Two 550 kW marine auxiliary turbo-generator sets for the Gulf Oil Company Ltd. are seen in fig. 3.

Particular interest attaches to the order placed by Colvilles Ltd. for the complete power station for their £20 million iron and steel project at Motherwell. This comprehensive contract, for which the G.E.C. is the main contractor, includes the building of the power house and associated civil engineering work; four Babcock and Wilcox boilers arranged for automatic firing by blast furnace gas and with oil burning standby equipment, each boiler having an evaporation

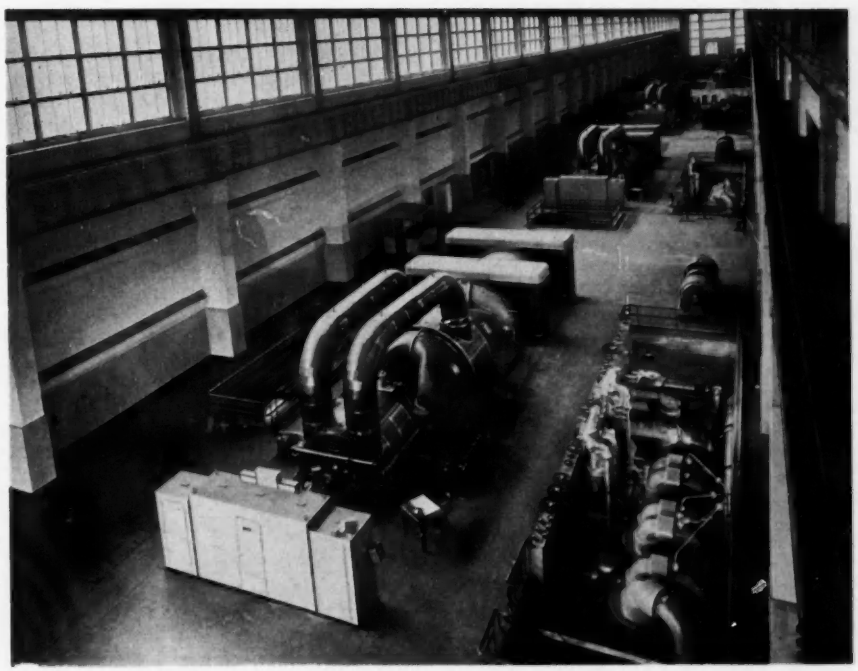


*Fig. 1.—Three 60 MW hydrogen-cooled turbo-alternators in the 360 MW Power Station at Uskmouth.*

capacity of 125,000 lb. per hour at 425 lb./sq. in. gauge, 825 deg. F. This building will house seven turbines and is laid out to allow for an extension to take two further sets. The plant under construction comprises three 10 MW turbo-alternators and two turbine-driven centrifugal blowers, each of 90,000 cubic ft./min. capacity, for supplying air at 32 lb./sq. in. gauge to the new furnaces. Process steam requirements for the coke oven by-product plant and the melting shop are supplied by two back-pressure turbines each driving circulating water pumps. Two ferro-concrete natural draught cooling towers of a capacity of 1,200,000 gallons per hour are also included in the contract.

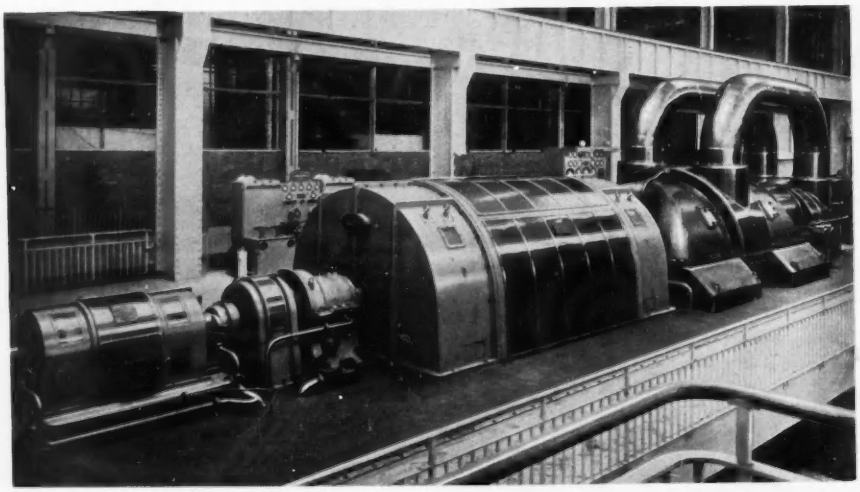


*Fig. 2.—One of two 30 MW turbo-alternators now in service at the Doncaster Power Station.*

The electrical equipment includes two 33/11 kV, 20 MVA transformers and all the associated switchgear comprising eleven panels of 33 kV, 750 MVA gear and twenty-five panels of 11 kV, 350 MVA and 250 MVA gear, 5 transformers and reactors and all low tension switchgear for the station, with necessary control gear for motor auxiliaries and the complete power cable and lighting installation.

The outstanding thermal performance recorded for the first 60 MW set in the Uskmouth Station has been confirmed by recent tests on the third set, which again prove these sets to have the highest efficiency ever recorded for machines of this rating operating at a steam pressure of 900 lb./sq. in. gauge and a temperature of 900 deg. F.

DEVELOPMENT.

Considerable development work during the year has resulted in designs of turbo-alternators for 120 MW and 200 MW capacity in a single line tandem arrangement. These developments make practicable still higher outputs for the future in cross-compound arrangement of steam casings.

These new sets are developed for a reheat cycle operating at the proposed standard conditions respectively of: 200 MW 2,350 lb. per sq. in. gauge 1,050 deg. F. reheat 1,000 deg. F.; 120 MW 1,500 lb. per sq. in. gauge 1,000 deg. F. reheat 1,000 deg. F. They embody many features of the sets now in service, in particular the adherence to a blading construction giving the highest performance and freedom from fatigue stresses, and main glands of the vernier type with complete freedom of axial expansion. In both these designs also it has been possible to develop blading to deal with the large volume of exhaust steam in only one double flow exhaust, thus easing the problems of expansion and so retaining fixed couplings throughout. By the use of only one thrust bearing no relative axial sliding is required at the couplings and there is in consequence no risk of thrust failures being caused by the large axial forces necessary to produce relative axial movement such as would occur with flexible couplings while transmitting heavy torque.

Sets of both ratings are designed to run at 3,000 r.p.m., and have three cylinders: high pressure, intermediate pressure and double flow low pressure. The steam at high pressure, and at high temperature after the reheat, is passed to an inner casing. This double shell arrangement reduces the pressure difference across the casings and eases thermal gradients and design stress.

Casings are provided with supporting lugs, the under surfaces of which are brought up level with the centre line of the turbine. In this way the centre line of the casings is maintained coincident with the centre line of the shaft over the whole range of temperatures from casings when cold to casings at maximum temperature. The casings are free to expand laterally, the supporting lugs sliding on their supporting sur-

faces on the pedestals. Lateral location of the casings is maintained by vertical keys on their centre planes.

All blading, apart from the velocity stages, is of vortex design in which the centrifugal forces from the whirl components of the steam flowing from nozzles to moving blades are balanced by a radial pressure gradient. This is effected by designing the blading with impulse conditions at the base diameter and with a degree of reaction increasing from root to tip. The moving blades are of twisted form so as to satisfy the continuity requirements of the vortex system and at the same time the inlet angle is varied to match the direction of the approaching steam. The same system provides optimum ratio of blade speed to steam speed at all diameters and the steam leaves all stages at every diameter in a substantially axial direction.

All wheels are provided with coverbands which, in conjunction with adequate blade stiffness and the avoidance of resonance with nozzle impulses by variation of the nozzle pitching, permit complete freedom from the use of lacing wires. The coverbands also permit a simple and robust system of tip sealing to be employed and on the low pressure stages serve to limit the extent of water erosion.

Normal governing is effected by a small, high-speed centrifugal governor driven from the turbine shaft which operates the four high pressure governing valves. These valves open simultaneously and at the same rate, the governing being by throttling with no nozzle control. In this way symmetry of steam admission to the casings is assured.

The high pressure emergency valves are also relay operated from the main governor and open simultaneously with the governing valves but at an increased rate. With this arrangement, the steam supplied to the turbine at small loads is throttled in both emergency and governing valves and results in very fine control and stable governing at small loads and during synchronising. At the same time the emergency valves move when small changes of load occur during normal service, which ensures that their spindles remain free.

In the event of sudden loss of load, the large quantity of steam stored in the reheating section of the boiler and in the connecting piping contains sufficient energy to produce an excessively high overspeed. The interceptor valves are provided to prevent the passage of this steam through the intermediate pressure and low pressure turbines and the dumping valves provide an alternative escape route.

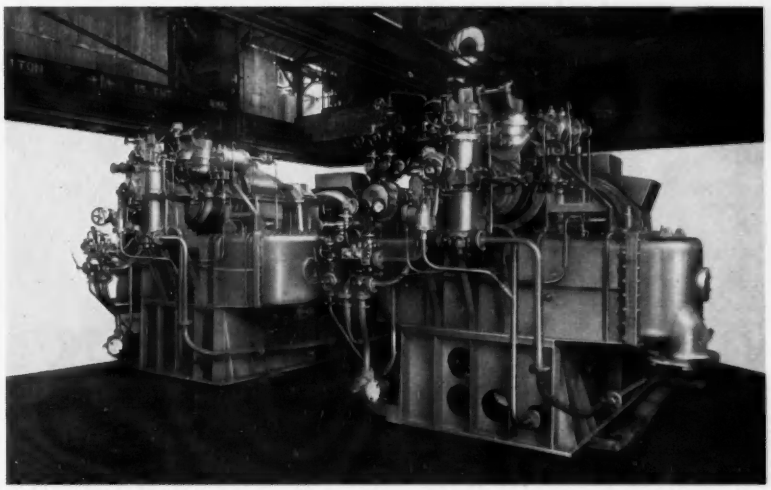


*Fig. 3.—Two 550 kW marine auxiliary turbo-generator sets for the Gulf Oil Co., Ltd.*

Interceptor and dumping valves are operated by a centrifugal speed governor driven from the turbine shaft, acting independently of the main governor. It is set to a higher speed value than the main governor and comes into operation if the speed rises above the no-load speed of the main governor corresponding to a main governor setting of normal speed at M.C.R.

In addition to the secondary speed governor, an acceleration-sensitive governor is provided, and in the event of sudden complete loss of load closes the high pressure emergency and governing valves, closes the interceptor valves and opens the dumping valves.

Means are provided for independent testing of the emergency overspeed governors and also for testing of the interceptor valves. The testing of the latter can be carried out on load, each interceptor valve in turn being rapidly closed and immediately reopened by relays provided for this purpose.

### CENTRIFUGAL AIR COMPRESSORS.

The Company has supplied a large number of centrifugal blowers and compressors since the inception of this type of machine which became universally popular about 1910. A prototype of a new design of

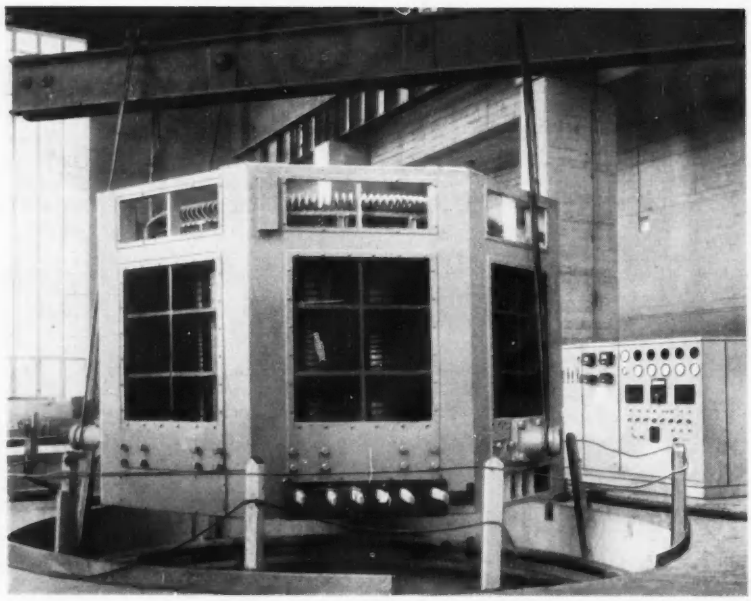


*Fig. 4.—The stator of a 31·25 MVA, 428 r.p.m. alternator being lowered into position at the Errochty Power Station of the North of Scotland Hydro-Electric Board.*

turbo-compressor described in this Journal last year is nearing completion at the Works and will soon be put into service for the National Coal Board at Mosley Common Colliery. Two blast furnace turbine-driven blowers on order for Colvilles, Ltd., form part of the comprehensive contract mentioned above for the new Motherwell Ironworks, and a further 90,000 cubic ft./min. turbine-driven blower has been ordered for their Clyde Ironworks.

In the past, the major demand for centrifugal machines has been for blast furnaces, but during the current year the field of application has widened, as a result of which a contract has been placed with the Company for a very large-scale test plant by the Ministry of Works. Each set comprises three centrifugal machines for series/parallel operation and for use as compressors or exhausters, and is arranged with a combined turbine and motor drive. The installation of two sets will total 88,000 h.p.

### GAS TURBINE AND DIESEL-DRIVEN GENERATORS.

For Williamson Diamond Mines a 750 kW, 3·3 kV, 1,500 r.p.m. alternator is being built which will be driven through gearing by a gas turbine of Ruston & Hornsby's manufacture. The plant is designed for service at an altitude of 4,000 ft. in an ambient temperature of 92 deg. F. and is built for an overspeed of 2,000 r.p.m. It will be recalled that previous orders received from this concern covered engine-driven sets rated at 900 kW; a contract recently placed covers two further engine-driven sets of this rating. Also for overseas service are a 3·3 kV 1,750 kW flywheel type alternator, three phase, 40 cycles,

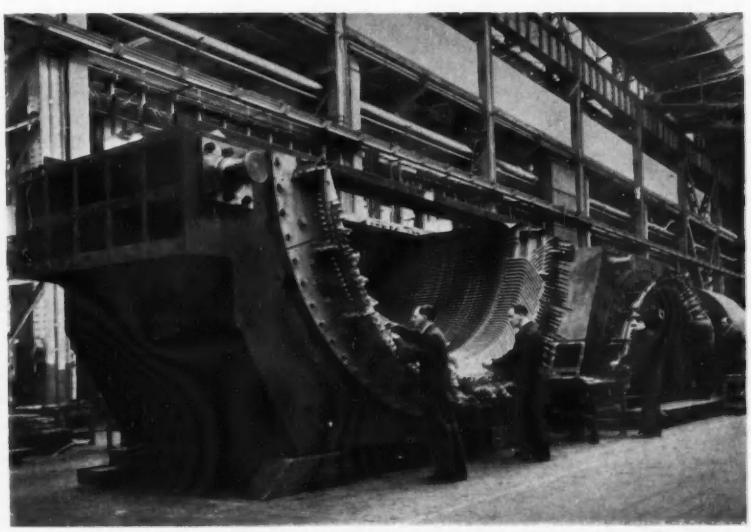


*Fig. 5.—The two halves of the stator in course of winding for the 62.5 MVA horizontal shaft alternator for Aura Kraftonlegg, Norway.*

218 r.p.m., for Lake View and Star Mines, Western Australia, five 1,080 kW sets for the Rangoon Electric Tramways and five sets rated at 300 kW and 200 kW for the Cawnpore Sugar Company.

### HYDRO-ELECTRIC PLANT.

At the Tungatinah Power Station of the Tasmania Hydro-electric Commission, which formed the subject of an article in an earlier issue of this Journal,* four of the five 31·25 MVA sets are now in service, while erection of the first two of three alternators of this rating for the Errochty Power Station of the North of Scotland Hydro-Electric Board is now complete. The stator of one of these machines is seen in fig. 4, being lowered into position on site. The construction of the 62·5 MVA horizontal shaft alternator for installation at Aura Kraftonlegg, Norway is now complete, the two halves of the stator of the machine being shown in fig. 5 in course of winding. Machining of the magnet wheel hub for this alternator is seen in fig. 6.

Hydro-electric plant is also being built for Uganda, two 2 MW horizontal shaft alternators being on order for the Kilembe Mines, Ltd. These machines will be driven at 600 r.p.m. by Gilbert Gilkes and Gordon water turbines and are to supply power at 3·3 kV.

*Fig. 7.—Insulation tests for 275 kV prototype transformer windings in progress.*

* *G.E.C. Journal*, Vol. XXI, No. 3, July, 1954, "Hydro-electric Plant at Tungatinah Power Station" by H. L. BARNARD.

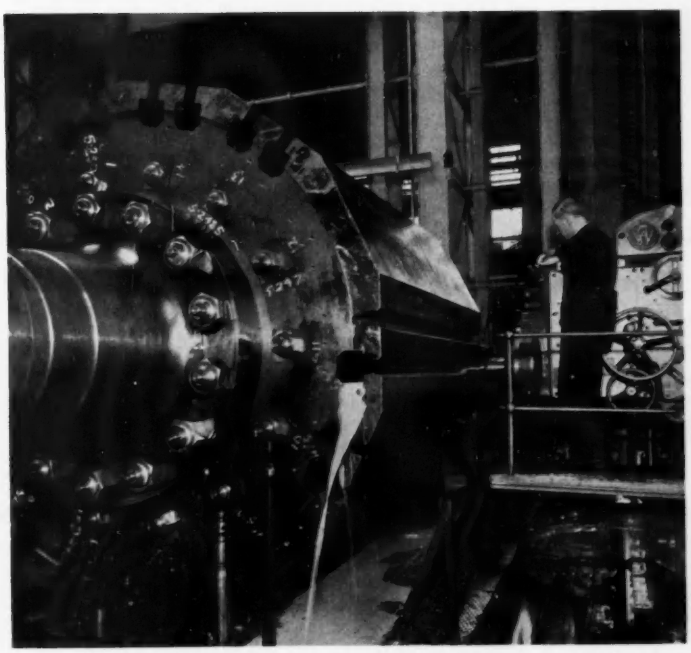


*Fig. 6.—Machining the tee-slots in the magnet wheel hub of the 62·5 MVA horizontal shaft alternator for Aura Kraftonlegg, Norway.*

### TRANSFORMERS AND CAPACITORS.

Further contracts have been received from the British Electricity Authority for alternator-transformers including three rated at 72 MVA for Hams Hall "C" power station, a further unit of the same rating for the Ince Power Station for which four are now being supplied, and two 36 MVA equipments for the Barony Station.

During the period under review, 45 MVA transformers have been commissioned for the outdoor substations at Crumlin, Cheltenham and Swindon, as well as further 70 MVA and 72 MVA alternator-transformers at the Uskmouth and Ince Power stations. The units for the Ince Power station are of interest in that use is made of a nitrogen seal so that the oil in the transformer is not in contact with the atmosphere. Nitrogen is chosen for this purpose as it is not absorbed by the oil, and, being an inert gas, it prevents oxidation and consequently retards the rate of deterioration of the oil.

The first of four 120 MVA, 275/132 kV auto-transformers for service on the Supergrid is in course of manufacture. The impulse voltage test level for the 275 kV windings exceeds a million volts and extensive studies of the electrostatic field using the electrolytic tank have been completed. In addition full-scale insula-

tion tests on model windings have been pursued in order to prove the design of the insulation, a test in progress being shown in fig. 7.

For the Toronto Hydro-electric System, fifteen 6,667 kVA, 60 cycle transformers have been delivered. Fans mounted directly under the radiators provide additional cooling, the fans being started automatically by switches in the temperature indicating apparatus.

*Fig. 8.—One of fifteen 6,667 kVA transformers for the Toronto Hydro-electric System showing the disposition of the cooling fans, control panel and tapping switch.*

The arrangement of the fans is seen in fig. 8, which also shows the control panel housing the winding temperature indicator and switchgear for their automatic control.

In situations where protection against fire risk is of paramount importance the transformer may be hermetically sealed and filled with Pyroclor, and a rectifier transformer of this design is being built for printing press drives for the " Montreal Star." Larger transformers may employ class B insulation and use a closed air circuit in conjunction with air-to-air heat exchangers to effect cooling. A complete transformer of this design is shown in fig. 9 and is one of six 500 kW rectifier transformers which are now in service in the Surrey Docks Substation of the London Transport Executive. Ten transformers of a similar design but rated at 750 kW are in course of construction for the Moorgate Substation.

A considerable amount of the equipment for the frequency changeover in the London area of the electrified system in the Southern Region of British Railways is now in service. One of the 2,500 kW rectifier transformers for this scheme is shown in fig. 10 from which it will be noted that extensive use is made of cable for the outgoing leads from the windings. This form of construction affords a definite improvement over rigid connections.

It has long been known that a single crystal of iron can be most easily magnetised in one particular direction. By a cold rolling process the crystals can be oriented so that the material is most readily magnetised in a direction parallel to the direction of rolling. If a transformer core is constructed so that the path of the flux is wholly, or nearly wholly, in the direction of rolling, the full advantages of low losses and low magnetising current are obtained. Furthermore the material can be operated at much higher flux densities than are possible with hot rolled steel with the consequent reduction in the size and weight of the transformer. Much progress has been made by British steelworks in the technique of producing this material which is becoming more readily available. Cold rolled steel is used in the 15 kVA, single-phase, 11,000/250 volt pole and platform mounted transformers, which are being supplied in quantity to the various Area Boards of the British Electricity Authority in connection with rural distribution schemes.

For the heavy current test plant which is used in connection with the development and testing of protective equipment, three single-phase transformers have been built capable of providing 44,000 amps. at 90 volts on an intermittent duty cycle. The transformers are specially constructed to minimise magnetic leakage, the arrangement of the heavy current leads being shown in fig. 11.

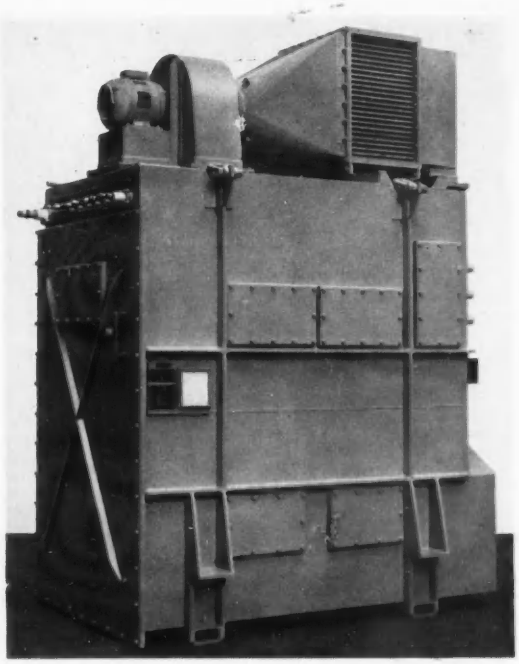


*Fig. 9.—500 kW air-cooled rectifier transformer for the Surrey Docks Substation showing the air-to-air heat exchanger.*

Important extensions to the test plant in the Transformer Works are nearing completion. The new equipment includes two 10,000 kVA water-cooled alternators, each driven at 1,000 r.p.m. by a 2,450 h.p. synchronous induction motor. These sets are designed to run in parallel with the existing test plant and also with the 4,000 kVA machine in the substation of the Heavy Engineering Works.

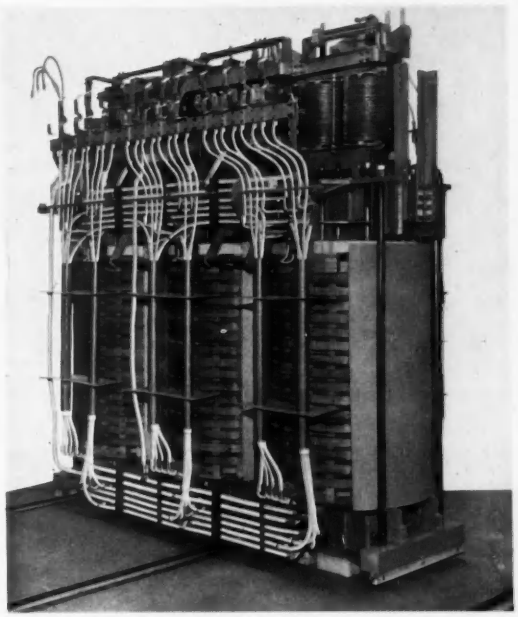


*Fig. 10.—A 2,500 kW rectifier transformer for the Southern Region of British Railways showing flexible cable connections.*

TRANSFORMER TAPPING SWITCHES.

Type tests on two new designs of on-load tapping switch, the type O and type P respectively, have been completed, and these switches are now in production. The type O switch is designed for service at 33 kV, 50 amp. and is fitted with selectors of the cam-operated contactor type which break the load current so that diverter switches are not required. Each bank of selectors is provided with an additional pair of contacts, tipped with tungsten alloy. These contacts operate in series with the selectors and provide a double break thereby increasing the maximum breaking capacity of the tapping switch.

The type P switch is suitable for service at 11 kV, 100 amp. and is similar in its construction to the type O switch with the exception that the series contacts are omitted. The operating mechanism of both these tapping switches is designed to afford maximum accessibility to the auxiliary control switches.

Fig. 12 shows six of the tapping switches for the 6,667 kVA transformers for the Toronto Hydro-electric System, to which reference has already been made. Although similar in design to the standard 33 kV type N switch, they are considerably smaller on account of the lower voltage of 11·2 kV.

CAPACITORS.

The standard range of capacitors has been extended by the introduction of two 3-phase, single-unit assemblies rated at 1·5 kVAr and 3·0 kVAr respectively to meet the demand for the individual power factor improvement of small motors. These capacitors are normally fitted with three exterior terminals, the three phases being interconnected internally, but for service with star/delta starters, six terminals can be provided, if required. Large quantities of these units have been supplied to the Gloucester Aircraft Co.

In the interests of economy, there is an increasing demand for equipment to provide automatic control of power factor, thus reducing to a minimum unnecessary current demand on the mains. A typical 6-step equipment of this nature, rated at 162 kVAr, for Hague & Mackenzie is seen in fig. 13.

OUTDOOR SWITCHGEAR.

The heavy demand for outdoor oil circuit breakers of 33 kV, 66 kV and 132 kV has continued throughout the year and much equipment has been despatched overseas particularly in connection with transmission schemes in India.

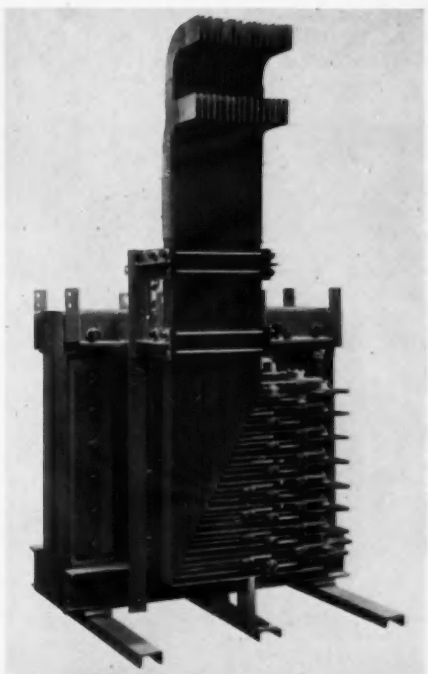


*Fig. 11.—44,000 amp. power transformer showing the arrangement of the heavy current leads.*

Reference was made in the progress review last year to the new design of 132 kV outdoor oil circuit breakers rated at 2,500 and 3,500 MVA ; many are on order, or in course of erection on site, for various substations of the British Electricity Authority. A group of these breakers in course of construction in the works is seen in fig. 14.

### Surge Diverters.

The range of surge diverters is now extended to include equipment for service at 290 kV, diverters of this rating being suitable for use on 330 kV systems with earthed neutrals. The 290 kV diverters are built up from standard 14 kV units using a self-supporting construction in which the amount of insulation used purely for structural purposes is reduced to a minimum.

### METALCLAD SWITCHGEAR.

Within the period under review the output of metalclad switchgear has considerably exceeded that of previous years. Much of the 33 kV, 750 MVA switchgear for the British Railways, Southern Region, is now in service, one of the substations being shown in fig. 15. It will be recalled that this contract covered over 300 units of this rating.

Metalclad switchgear of this rating has recently been commissioned in the Eastleigh Substation of the Southern Electricity Board and the Smethwick Substation of the Midland Electricity Board, while at Brisbane, Australia, seven units rated at 33 kV, 500 MVA are now in service. For the West Bank and Bloemfontein Power Stations in South Africa, 11 kV metalclad gear with 2,000 amp. breakers has been installed, the former including ten 750 MVA units and the latter, fifteen 500 MVA units. Nineteen 6·6 kV heavy metalclad units are being installed at the Hackney Power Station of the British Electricity Authority, four rated at 500 MVA, with heavy current circuit breakers of 3,000 amp. capacity and fifteen at 350 MVA.

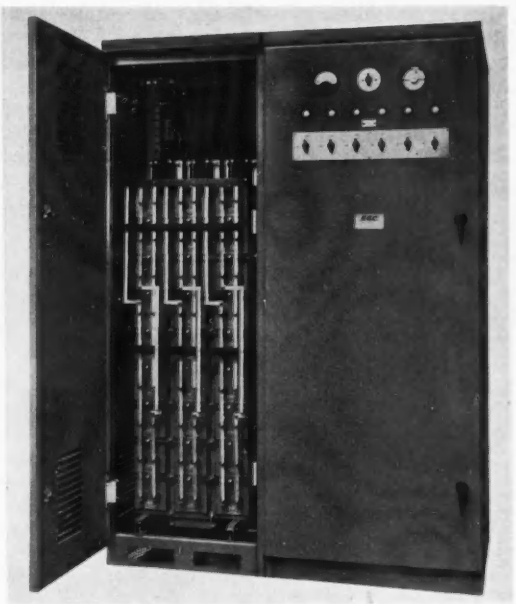


*Fig. 13.—162 kVAr, 6-step capacitor equipment for automatic power factor correction.*

In the smaller range, twenty-seven 6·6 kV, 150 MVA units with single break circuit breakers (fig. 16) are in service at the St. Sampson's Power Station of the Guernsey States Electricity Board which was officially opened towards the end of last year. A thirteen panel board rated at 11 kV, 250 MVA has been commissioned at the Longbridge Substation of the Midlands Electricity Board.

Orders recently placed include eleven 33 kV units for the Eastern Electricity Board and two 10-panel

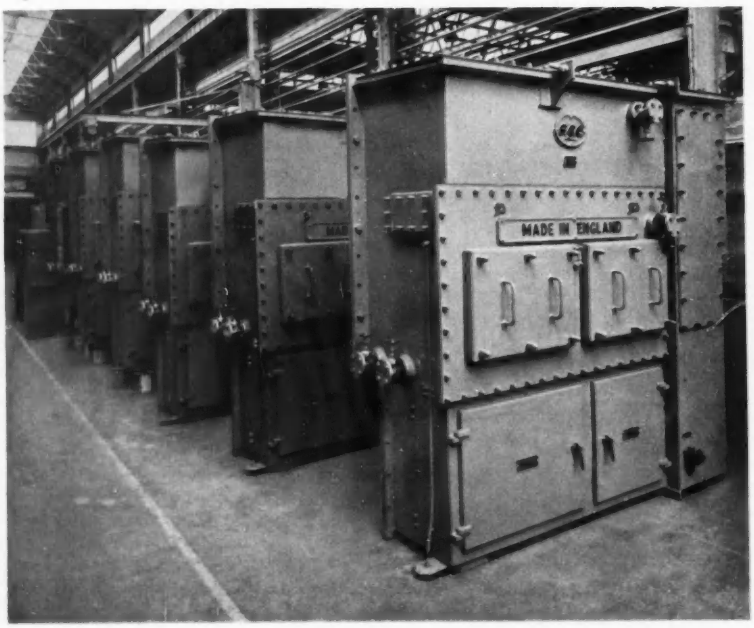



*Fig. 12.—Tapping switches for the 6,667 kVA transformers for the Toronto Hydro-electric System, awaiting despatch.*

11 kV boards rated at 250 MVA and 500 MVA respectively, for the Midlands Electricity Board and the Ballapur Power Station Bombay.

The load breaking, fault-making oil switch which was described briefly in the progress review last year, is now available in several forms; as an extensible ring main unit with air, compound, or oil-insulated busbars; for mounting between 11 kV metalclad units of the single break type, or as a non-extensible ring-main unit. The last mentioned is shown in fig. 17. The oil switches are mounted above the circuit breaker in the space normally occupied by the busbars of a standard metalclad unit, and can be closed in safety on to a fault up to a maximum of 250 MVA at 11 kV. This unit complies fully with the relevant B.S. now in draft form. A simple, robust and comprehensive system of interlocking affords complete safety against maloperation while provision is made for accommodating current transformers for metering or protection.

*Fig. 15.—33 kV, 750 MVA metalclad switchgear in the Wimbledon 'B' substation of the Southern Region, British Railways.*

*Fig. 14.—132 kV, 2,500 MVA outdoor oil circuit breakers in course of assembly.*

## IRONCLAD SWITCHGEAR.

The new ranges of ironclad switchgear referred to last year have been further extended. In the DW range a new 60 amp. single-pole and neutral splitter is in course of development.

For the general industrial field, which is covered by the MW range, additional accessories including cable boxes and reverse entry boxes for the switchfuse units are in production and the range is being extended. Also in this range are new designs of 20 amp., 500 volt fuseboards which line up with those rated at 30, 60 and 100 amp. The new boards embody a semi-enclosed fuse unit giving improved performance. The bases may be fitted with holders for H.R.C. fuses if desired.

Double-pole, triple-pole and triple-pole and neutral switches are now included in the HW range. The switchgear in this range is weatherproof and is intended for service where conditions are severe and protection against dust and moisture is essential.

## PROTECTIVE SCHEMES AND RELAYS.

### Type M Relay.

Experience shows that in many instances the relay is the limiting feature in the design of protective schemes. To satisfy the exacting requirements of modern systems of protection, a relay must meet the following conditions: (*a*) high sensitivity (i.e. operation with a

low power input), (*b*) high speed, (*c*) high ratio between overload capacity and minimum operating power, (*d*) suitability for accommodating bias or restraining windings, (*e*) simple and robust construction and (*f*) positive contact action.

During the past year several new relays have been designed with the above objects in view. One of the most interesting of these is the polarised moving iron relay, type M, which possesses the advantage that it can be readily adapted for a wide variety of applications, a few typical examples of which are described below.

The relay itself, the components of which are shown in the exploded view (fig. 18), uses a permanent magnet to produce the main flux so that the input power required by the control windings is small, being as low as 0·003 watts for some applications. This design affords many advantages over moving coil relays, the more outstanding being :

(1) There are no flimsy ligament connections either to the coils or contacts.

(2) The ratio of torque to inertia is high and rapid operation is obtained without prejudice to the ability of the relay to withstand vibration and shock.

(3) The relay will withstand a 2 kV pressure test between windings, contacts and the relay frame, and between the "operate" and "restrain" windings.

(4) The relay contacts are capable of directly operating a circuit breaker trip coil.

(5) It is not necessary to transform the relay current to a particular value, because the relay may be wound for a wide range of currents or voltages.

(6) Its strong construction facilitates inspection and maintenance.

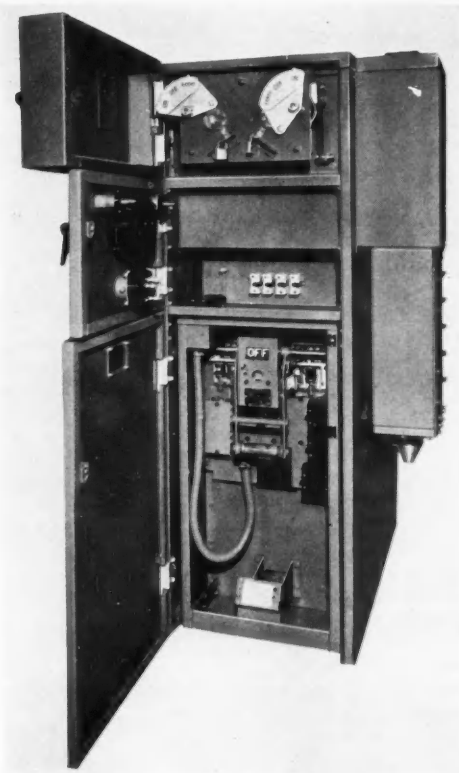



*Fig. 17.—Non-extensible ring main unit fitted with load-breaking, fault-making oil switches.*

*Fig. 16.—6·6 kV, 150 MVA metalclad switchgear at St. Sampson's Power Station, Guernsey.*

**Feeder Flow Overload Alarm Relay.**

One adaptation of the M relay is the feeder flow overload alarm relay, type MOC (fig. 19), which meets the demand for a relay responsive to A.C. current and having a 10 per cent. pick-up/drop-off differential. The setting adjustment is continuously variable over a 2 : 1 range which in the standard relay is 80-160 per cent.

**Earth Fault Protection Relay.**

Earth fault protection is provided by the type MCB relay, which represents another adaptation of the type M relay. In this instance the type M relay is used in combination with a standard core balance current transformer of the mumetal type. A wide range of applications is covered by this apparatus, a

typical example being shown in fig. 20 which illustrates the scheme for a coal washing plant. The advantages of this relay are :

(*a*) An earth fault setting of 5 amp. is always obtainable regardless of the full load current of the circuit or group of circuits protected.

(*b*) The phase fault stability factor exceeds 1000 : 1.

(*c*) From the point of view of thermal and magnetic stresses, the relay can be used for any current irrespective of the short-circuit level of the system.

(*d*) Operation is instantaneous.

(*e*) Protection can be afforded to groups of circuits so that costs are considerably reduced as compared with systems in which individual protection is provided for each circuit.

**Overvoltage and Undervoltage Relays.**

Overvoltage and undervoltage relays, types MOV and MUV, represent further versions of the type M relay. They are designed to function as instantaneous voltage relays with low pick-up and drop-off differentials for service in control and protective schemes. Standard setting ranges are 60-85 per cent. for the undervoltage relay, type MUV, and 115-160 per cent. for the overvoltage relay, type MOV.

Other relays recently introduced include a voltage regulating relay, an instantaneous differential protection relay, type PV, and a range of high-speed tripping relays.

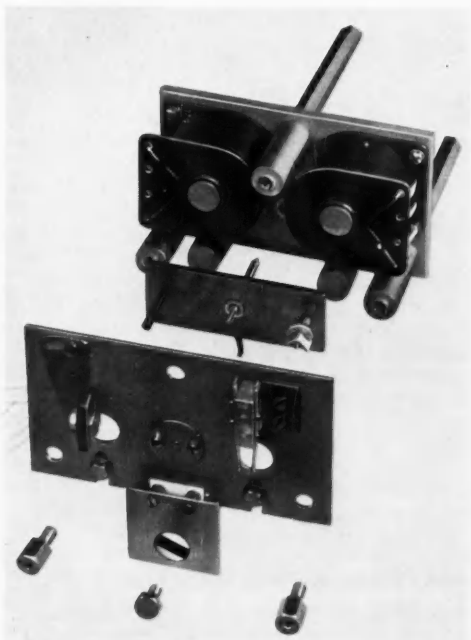


*Fig. 18.—Exploded view of the type M polarised moving iron relay.*

**Voltage Regulating Relay.**

The voltage regulating relay, which operates in conjunction with a line-drop compensation unit, has been developed in response to a demand for an accurate voltage regulating equipment for use with transformer tap-changing gear. The main voltage detecting element is a robust and sensitive D.C. moving coil relay which is connected to a rectifier fed from a small interposing voltage transformer.

Variation of the operating voltage over a range of ambient temperatures from minus 15 to plus 40 deg. C is within $\pm$ 0·156 per cent., and is less than 0·1 per cent. per cycle deviation from the rated frequency.

*Fig. 19.—Feeder flow overload alarm relay, type MOC.*

The line-drop compensating unit associated with the relay enables the voltage at a point remote from the power transformer to be held at a constant value. This unit corrects the voltage applied to the relay by an amount corresponding to the voltage drop in the network between the power transformer and the remote busbars. Hence the relay follows the voltage at the remote busbars accurately, irrespective of the value of the load and its power factor. The circuit is shown in fig. 21.

The components are calibrated to provide compensation for a maximum of 10 per cent. resistance and 10 per cent. reactive voltage drop in the system under full load conditions. The actual setting of the voltage at the remote busbars may also be adjusted by $\pm$ 10 per cent. The equipment has been tested under conditions of varying temperatures, frequency, load and power factor, and complies with accuracy requirement, Class 1, of the (American) A.S.A. standards and relevant British Standards, which stipulate that the maximum value of the summated errors shall not exceed 1 per cent.

Fifteen of these equipments have been supplied for service with the control gear associated with 6,667 kVA transformers built for the Toronto Hydro-electric System.

**Instantaneous Differential Relay.**

The instantaneous differential relay, type PV, is a high impedance relay which is calibrated in voltages and incorporates a voltage limiting non-linear resistor. It has been introduced for use in circulating current, differential protective schemes and supersedes the conventional combination of a current-operated relay and stabilising resistor. Its advantage is that more sensitive settings are obtained for the same stability levels.

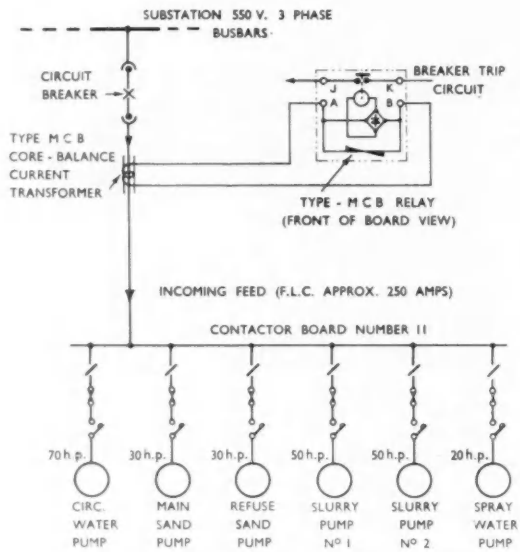



*Fig. 20.—Application of core balance protection, type MCB, for a coal washery.*

**High-speed Tripping Relays.**

A range of high-speed tripping relays with an operating time of 10 milli-seconds has been introduced. These relays are available in six types according to the number of contacts for external circuits and the type of reset feature, i.e. electrical, hand or self-reset.

Relays types DEA and DEB (fig. 22) are arranged for electrical or hand resetting and are provided with six or fourteen contacts respectively. In types DHC and DHD hand reset only is provided, the number of contacts being seven and fifteen respectively. The type DSA (six contacts) and the type DSB (fourteen contacts) are of the self-reset pattern. In all cases the contacts, which provide a double break, will close a 30 amp., 250 volt D.C. inductive circuit and break a 1 amp. circuit at the same voltage. Any combination of " make " and " break " contacts can be arranged. The tripping and reset solenoids have a momentary consumption of 150 watts, the solenoid circuits being opened as soon as the relay has operated. In the case of relays of the self-resetting pattern, types DSA and DSB, a contact on the relay is used to introduce an economy resistor in the solenoid circuit, the resistor being mounted externally.

**TEST LINK BOXES.**

A new design of meter testing link box has been developed to make good the recognised deficiences of the more orthodox form. It fulfils all the requirements of the engineer when testing and commissioning protective equipment.

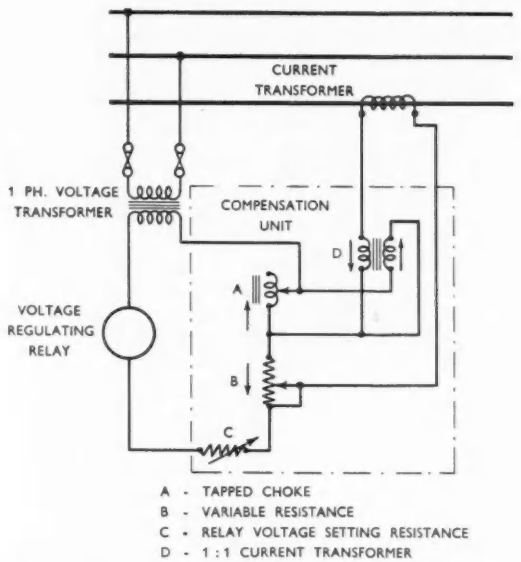



*Fig. 21.—Circuit arrangement of a voltage regulating relay with line-drop voltage compensation.*

This box is extensible, but standard patterns are provided with 3, 6 or 10 ways. Any combination of changeover or single-pole links is available for use when measuring current. Each changeover link comprises one open and one closed link, so that when used in current transformer circuits, the transformer secondaries can be positively short-circuited before an ammeter is connected in the circuit. Bronze screws hold the links in position and can be tightened with a box spanner or screwdriver. Barriers prevent accidental contact of adjacent links, while ample space is available for labelling each link. Terminals are provided for use when making voltage measurements, while external terminals for the various instrument leads are provided with insulated heads.

**COMPENSATED OIL DASHPOT.**

The use of the simple oil dashpot in timing devices has always been severely restricted because of the wide

change in the viscosity of the working fluid with temperature. The advent of silicone fluids effected much improvement, but even with these fluids large variation of ambient temperature may cause unduly large variations of operating time.

In a device recently developed, variation in operating time is largely eliminated. It is essentially a simple oil dashpot but has a by-pass valve fitted in the piston. This valve is opened and closed by a bimetallic element so that the flow through it is controlled by temperature. The valve is designed with reference to the viscosity temperature characteristic of the working fluid, and in dashpots so far developed a temperature variation of 90 deg. F causes only a 10 per cent. change in the operating time. The characteristic of the device is evident from fig. 23.

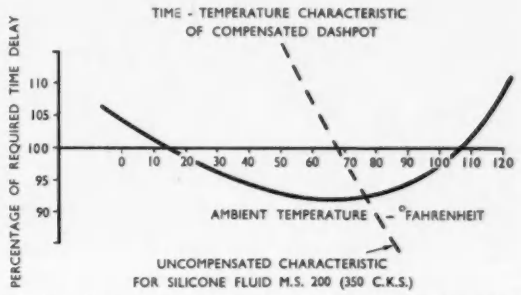



*Fig. 23.—Time-temperature characteristic of the compensated oil dashpot.*

**CABLE.**

The shortage of lead during the years immediately following the war led to the development of techniques to enable aluminium to be used as an alternative sheathing material for underground cables.* Various methods of sheathing were considered ; the one finally adopted involved the formation of tube from strip welded longitudinally. Continuous automatic welding equipment was employed making use of the patented twin-arc electrode and control system with an inert gas shield, in this case argon.

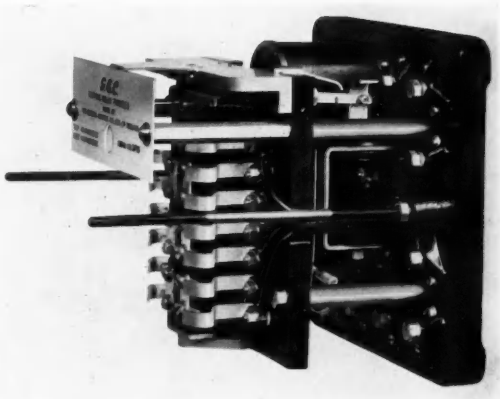


*Fig. 22.—Tripping relay, type DEA, with cover removed.*

A second machine for applying aluminium sheaths by the twin-arc argon process has been installed at Pirelli-General Cable Works, and is now in production. It incorporates the same general design features as the unit already in use for heavier cables, but provides the necessary higher precision in supporting and forming the thinner gauges of aluminium strip which are used in the manufacture of cables from about $\frac{1}{2}$ in. to 1 in. dia.

It is expected that this machine will be used extensively for sheathing cables having asbestos, rubber and plastic insulations as well as for paper insulated pilot and telephone cables. The machine and control cabinets are seen in fig. 24.

New plant has also been installed for the vacuum impregnation of non-draining paper insulated cable and for the preparation of the special non-draining impregnating compound. This is to meet the growing demand for cables in accordance with the dimensional requirements of the revised British Standard No. 480, and complying also with the test specified therein for the non-draining properties required in cables to be laid on steep slopes or in vertical runs. It is now possible to manufacture non-draining cables of all types for voltages up to and including 11 kV.

**MERCURY ARC RECTIFIERS.**

In order to meet the continued heavy demand for rectifier plant, important extensions have been made to the Works, and a further 12,000 sq. ft. of manufacturing floor space have been brought into service.

Earlier progress reviews have recorded many applications of the grid-controlled rectifier of both multi- and single-anode designs in an ever-widening field. Much experience has been gained of their operation in service, and opportunities have been forthcoming to study their behaviour under conditions which would have been difficult to anticipate or reproduce on the Works test bed. The knowledge thus acquired has resulted in further improvements in design to ensure even greater reliability and accuracy of performance of the grid-controlled rectifier.

A large volume of plant has been commissioned overseas, including two 1,224 kW, 1,530 volt grid-controlled equipments for the Netherlands Railways from whom a further order is in hand for thirteen rectifiers of the same rating with electronic arc suppression gear. This new order brings the total capacity of rectifier plant for these railways up to 46,000 kW.

The commissioning of eight 1,500 kW, 1,600 volt rectifiers by the New Zealand Government Railways

* "Aluminium Sheathed Cable" by B. O. Ashford, J. A. Donelan and J. R. Penrose, *G.E.C. Journal*, Vol. XIX, No. 4, October, 1952.

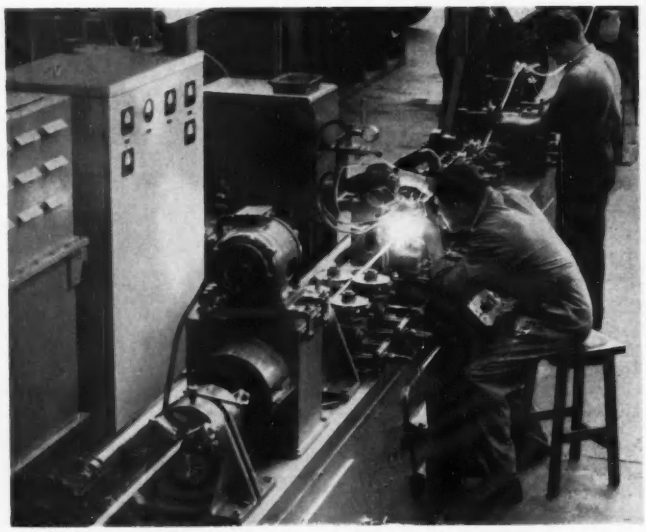


*Fig. 24.—Aluminium sheathing machine for cables of small diameter.*

is of more than passing interest. Although these rectifiers were held in store since they were delivered over three years ago, no difficulty was experienced in bringing them into service. Immediate and successful operation after a storage period of this length substantiates the claims made for the vacuum and degassing technique used in their manufacture. Also delivered overseas within the period under review are four 1,250 kW, 625 volt rectifiers for the Hague Supply Co., a 710 kW 1,230 volt equipment for Hague Trams, two 1,000 kW rectifiers for the Melbourne and Metropolitan Tramways Board, a 1,500 kW, 1,500 volt unit for the Victorian State Railways, 2,100 kW of plant for the Kanpur Electric Supply Co., and two 1,200 kW equipments for the Estoril Railway, Portugal.

Other overseas orders include two 400 kW rectifiers for Hong Kong, a 750 kW unit for Delhi Cloth Mills and two rated at 250 kW for the Royal N.Z. Naval Dockyard, Devonport, New Zealand. A 700 kW equipment is also on order for the Bombay Works of Laporte Chemicals.

In connection with the frequency conversion scheme of the Southern Region of British Railways for which forty-nine 2,500 kW equipments are being supplied, several substations are now in service including those at Nunhead (fig. 25), South Bermondsey "A", Blackfriars, Croydon, Selhurst "A" and Brockley. In addition more than 8,000 kW of plant have been brought into service for industrial concerns in this country, including equipments for Appleby Frodingham Steel Co., Ltd., Tube Investments Ltd., Stewarts & Lloyds, Thames Board Mills and Tullis Russell & Co., Ltd.

The volume of business in both the home and overseas markets is well maintained and the number of repeat orders is particularly satisfying. Of the home orders, mention may be made of the six 2,400 kW equipments for the Caplaw Hill and Whitevale substations of Glasgow Corporation Transport. Also for traction duty are 300 kW units for the Teeside Railless Traction and the British Transport Commission at Bristol. Further orders have been placed by Laporte Chemicals covering an 1,800 kW and two 900 kW rectifiers. Repeat orders from Appleby Frodingham, Richard Thomas & Baldwins, the Brightside Foundry, and the Thames Board Mills represent over 7,000 kW of plant. For Dorman Long & Co. Ltd., orders in connection with their expansion programme are in hand. These cover two 300 kW and three 2,150 kW rectifiers, the latter being grid-controlled for supplying power to the slabbing mill auxiliary drives. An order received for a 250 kW rectifier for the Darwen & Mostyn Iron Co., Ltd., Flintshire, is of interest. Its primary purpose is to provide power for a blast furnace, but it will also be used to supply lighting to the village adjoining the works.

The application of the single-anode rectifier with grid-control features to printing press drives was described at some length in the previous progress

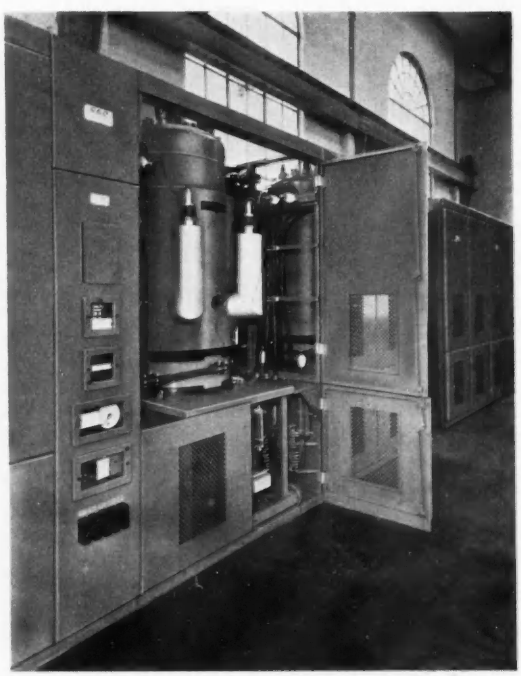


*Fig. 25.—2,500 kW rectifier equipment in the Nunhead Substation of the Southern Region, British Railways.*

review. It will be recalled that these units are connected through fault-limiting reactors directly to the 3-phase LV supply and thus provide a very compact converting equipment free from oil-filled transformers and switches. Recent orders for this type of rectifier cover fifteen 6-cylinder units for Witton-James printing press drives, and include equipments for Odhams Press. Also in hand for printing press drives are three multi-anode equipments for the Montreal " Standard " and the Kemsley Press.

The success of the electronically controlled drive has been confirmed during the past year by the number of orders received for this type of equipment, at least half of them being repeat orders.

Contracts in hand now bring the number of equipments supplied or on order to 37, the total rectifier capacity involved amounting to more than 12,500 kW together with 124 D.C. motors totalling 6,500 h.p. On the completion of present contracts, these equipments will have been installed in 18 printing offices, mostly those of large newspapers, in seven countries on four continents. Five equipments are for driving high-speed rotary gravure presses where the excellent speed control will be of particular importance in increasing production and reducing waste copies. One of these equipments, designed for operation from a 60 cycle supply, is for service in Montreal, and will be the first completely British-built equipment of its kind to be installed in Canada. It is of interest that Witton-James have introduced similar equipment into Denmark, Australia, Italy, Finland and South Africa.

In last year's review of progress mention was made of the use of electronic control in enabling a new reel of newsprint to be spliced to an expiring reel at full printing speed. This has materially increased the effective output of the printing presses, particularly where unskilled labour and poor quality newsprint are concerned.

Developments in progress include an extension of electronic control, and the application of germanium photo-cells to the control of the newsprint web in the printing press.

*Fig. 26.—250 kW rectifier in service on the Colombo Municipal Tramway system. These are the first rectifiers of this type to be installed in Ceylon.*

# Mining Equipment

## WINDING ENGINES.

Dynamic braking of A.C. winders is rapidly becoming a standard requirement, and for many winder orders now in hand, the new system of speed control is also being incorporated. This method of control formed the subject of an article in an earlier edition of this Journal*.

The 1,550 h.p. geared A.C. skip winder for No. 2 shaft at Manvers Main Colliery is now in service. The winder, which is shown in fig. 27 is raising 6 tons per wind from a depth of 1,143 ft.

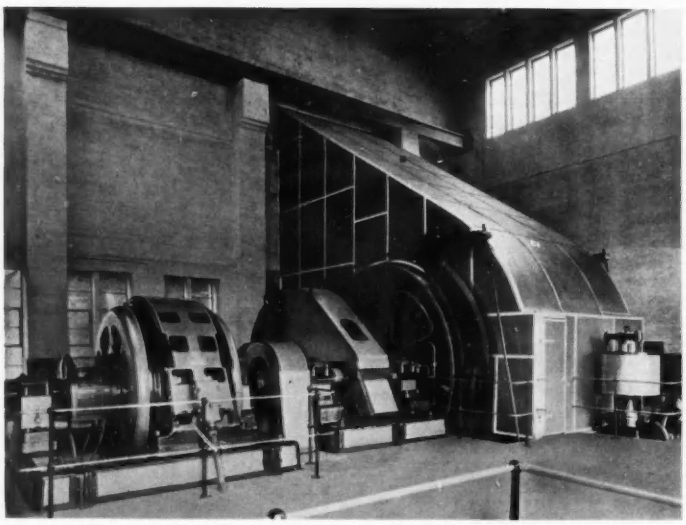


*Fig. 27.—1,550 h.p. geared A.C. skip winder at No. 2 shaft of Manvers Main Colliery.*

It will be recalled that this system maintains a close relationship between the rope speed and the position of the driver's lever, so that the operation of the A.C. winder approaches closely to that long-established for D.C. equipments using Ward-Leonard control with overriding current limitation.

The first winder in this country to use this control scheme was commissioned at the Avon Colliery, Blaengwynfi, South Wales, in July, 1954. An existing steam winder was replaced by an electric winder having a 12 ft. dia. single drum driven by a 1,100 h.p., 3·3 kV, 475 r.p.m. motor through single reduction gears. It is noteworthy that the winder with the new form of control was successfully installed, tested and the final trials with loaded cages completed within the sixteen days' annual shut-down at the colliery.

A further steam winder manufactured by Fraser & Chalmers was converted to electric drive at Chanters Colliery, the new equipment comprising a 13 ft. dia. drum driven by an 875 h.p. motor. This conversion was also carried out during the sixteen days' annual shut-down.

Further winders put into operation during the period under review include the mechanical parts of two 15 ft. dia. single drum winders at Bold Colliery, and a 24 ft. dia. single rope Koepe winder together with a rope changing winch at Bradford (Manchester) Colliery (fig. 28). This is the first large Koepe wheel to be put into operation in this country and is designed to raise coal from three levels, 2,802 ft., 3,312 ft. and ultimately 3,822 ft. The machine is a skip winder, each skip having a capacity of 12 tons of coal, and the total load on the winding rope cappel being 42·75 tons.

A 14 ft. dia. double drum winder and a 13 to 20 ft. dia. bi-cylindro-conical drum winder have been installed at Mardy Colliery, South Wales. Further, a drum, brake engine and associated equipment were replaced at Markham Colliery.

Recent orders include the mechanical parts for a 10 ft. dia. double drum winder for the Anglo-American Corporation of South Africa and the mechanical parts of a 12 ft. dia. double drum winder for West Rand Consolidated Mines which will be made in South Africa from drawings and design data prepared at Erith.

* "Speed Control of A.C. Winders" by E. FRIEDLANDER, S. A. G. EMMS and C. A. MAER, *G.E.C. Journal*, Vol. XX, No. 3, July, 1953.

An order has also been received for a 14 ft. double drum winder for St. John d'El Rey Mining Co., Ltd.

On order for the National Coal Board is an 880 h.p. equipment for the conversion of the steam winder at Llanhilleth Colliery to electric drive. For this winder dynamic braking with speed control will be provided. A 650 h.p. winder is on order for the Glenrhondda Colliery.

DEVELOPMENT.

In view of the present trend towards tower mounted multi-rope Koepe winders and automatic winders, which is becoming more pronounced both at home and overseas, much development work is being carried out in this field. In this connection, an order has been placed by the National Coal Board for two 4-rope Koepe winders for the re-development at New Monckton Colliery in the Carlton area of the N.E. Division.

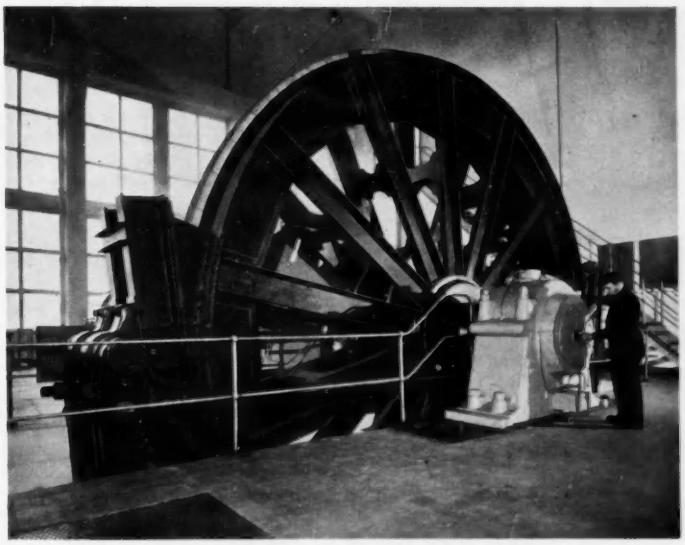


*Fig. 28.—Koepe winder at Bradford Colliery, Manchester.*

Particular interest attaches to the order received from New Consolidated Goldfields, Ltd. for a 4-rope Koepe winder which will be among the largest of its type to be built. The winder will raise gold bearing ores for the Driefontein Gold Mining Co., Ltd., and is designed to raise a skip load of 14 short tons from a depth of 5,460 ft. The 4-rope drum is 17 ft. 6 in. dia., and the total suspended load on the 26 in. dia. bearings will be some 120 tons. The mechanical parts, with the exception of the reduction gears, will be constructed in South Africa by the East Rand Engineering Co., Ltd. from drawings and design data provided by Fraser & Chalmers. The electrical equipment, which will be built at the Witton Engineering Works, comprises two 2,050 h.p. D.C. motors, a 3,800 h.p. motor-generator set for Ward-Leonard control of the winder motors as well as all associated control gear. A notable feature of this installation is that provision is made for push button control by the onsetter at the bank in addition to normal hand control by the winding engine driver.

PORTABLE MINING SUB-STATIONS.

In order to comply with the National Coal Board specifications Nos. 40 and 41, and to satisfy the primary circuit breaker requirements in certain areas, circuit breakers can now be fitted on both the primary

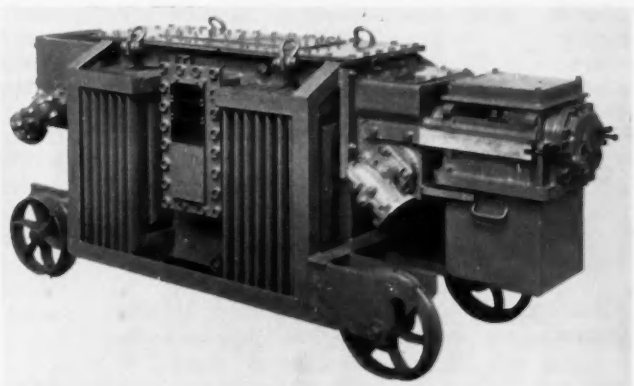


*Fig. 29.—150 kVA portable mining substation with high voltage circuit breaker, low voltage connection and metering chamber.*

and secondary sides of the transformer (fig. 29). Alternatively, adapters are available to facilitate the fitting of an isolator or cable plugs on the primary side where this arrangement is preferred. For the secondary side a cable adaptor with provision for accommodating an ammeter and voltmeter may be fitted in place of the circuit breaker.

FLAMEPROOF " LITEALARM " UNIT.

This alarm, which is illustrated in fig. 30, has been designed to comply with British Standard No. 229/1946, and is certified in Groups I, II and III. It was developed primarily for use in the oil and chemical industries and in power plants. Its function is to give visible and audible warning of the approach of such conditions as would eventually cause an interruption or complete breakdown of the plant. It will, for example, give warning of the overheating of pumps or driving motors ; excessive pressure, gas or hydraulic; over-speeding; and the occurrence of a dangerous level of fluid in tanks.

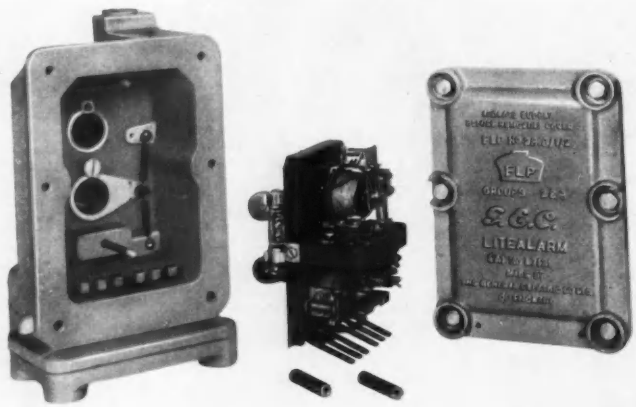



*Fig. 30.—Flameproof " Litealarm " Unit.*

It can be adapted for many other applications, either as a straightforward alarm or as a combined alarm, indication and control unit, and has the advantage of being interchangeable with American equipment with which it compares in overall dimensions. Normal operation is from a 100/130 volt, 40/60 cycle A.C. supply, but alternative voltages can be utilised. A feature of the " Litealarm " is the simplicity with which the more vulnerable components can be withdrawn and replaced if necessary. Testing facilities allow the operation of all components to be checked during normal working.

A pair of normally open or normally closed contacts are mounted within, or on, the apparatus to be protected, the alarm unit being placed at a remote point, such as in a central control room. With a two-light unit the green light is on when conditions are normal, indicating that the circuit is complete, and the red light is off. As soon as an abnormal condition develops the contacts are operated, the green light is extinguished and the red light begins flashing.

Simultaneously a relay closes the hooter circuit and provides an audible alarm. The operator in the control room at once cancels the audible alarm by operating a centre biased resetting switch and automatically the red light changes to a steady state. Appropriate action is then taken to correct the abnormal conditions. As soon as the plant returns to normal the red light is automatically extinguished, the green light comes on and the alarm unit is again in its normal operating state.

Where a second abnormal condition can arise, the three-light unit is used. The automatic warning and cancelling features are similar to those on the two-light unit, that is, the green light is normally on and when abnormal conditions arise it is extinguished and the hooter operates, but now a flashing amber light appears. Upon resetting, the hooter is silenced but the amber light remains on in a steady state and the circuit returns to normal only when the fault is cleared. If now a second abnormal condition occurs, another relay operates and again the green light goes off and the hooter sounds, but now the red light begins flashing. Upon resetting, the hooter is silenced but a steady red light continues to show until the abnormal conditions are removed, when the circuit again returns to normal and the green light reappears.

The two-light unit has been adapted for open or closed circuit systems for use in mines. With the increasing amount of machinery underground the unit is admirably suited to give warning of abnormal conditions during working hours, as it is impossible for men underground to see what is happening to equipment unless they happen to be on the spot at the time. The many mining uses include signalling, motor control, temperature alarm, substation alarm and protection of loading points when large coal is being conveyed.

# Mechanical Engineering

MINING AND GENERAL.

A Bauxite crushing and washing plant has recently been installed, and is now in operation, in West Africa. Undesirable silica is carried in the fine fraction and the purpose of the plant is to wash the fines from the coarse particles.

*Fig. 31.—Bauxite conveyors to the double roll crusher and the 500-ton storage bin.*

A 48 in. by 4 ft. Sherwen vibrating grizzly, with 9 in. spacing, feeds the ore to a 36 in. by 24 in. jaw crusher, which discharges to a 60 in. by 12 ft. Gyrex screen fitted with a 3 in. screen cloth. The oversize from the Gyrex screen is then reduced to minus 3 in. by a Fraser & Chalmers double roll crusher.

A series of conveyors delivers the material into a 500-ton capacity steel bin. The minus 3 in. ore is then taken from the bin by an overhead ropeway to the crushing plant. Fig. 31 shows the conveyors to the double roll crusher and the 500-ton bin for aerial ropeway feed. This illustration also shows the terrain in which the plant is situated.

The bauxite from the crushing plant is delivered by the ropeway to the washing plant bunker of 50 tons capacity which is designed to prevent the build-up of sticky material. To achieve this a 36 in. wide by 19 ft. 3 in. apron feeder removes the material from the complete length of the bin bottom.

The washing is carried out in a 6 ft. dia. by 29 ft. long revolving scrubber divided into washing, screening and dewatering sections. In the screening section the clean minus 3 in. by $\frac{1}{4}$ in. fraction is separated. The minus $\frac{1}{4}$ in. material flows by gravity on to a 60 in. by 12 ft. Sherwen screen where a separation is made at $\frac{1}{16}$ in. The minus $\frac{1}{4}$ in. by $\frac{1}{16}$ in. joins the plus $\frac{1}{4}$ in. clean bauxite.

The minus $\frac{1}{16}$ in. fraction passes to a 4 ft. wide by 28 ft. long rake classifier fitted with a 10 ft. dia. bowl. Here separation at 60 mesh or 120 mesh can be made. The raked product joins the clean concentrate and the bowl overflow material is pumped to waste. Fig. 32 shows the scrubber and screen, the Sherwen screen and, in the right background, the aerial ropeway delivering the crushed ore to the 50-ton bin. The plus $\frac{1}{4}$ in., plus $\frac{1}{16}$ in. and the classified raked product are conveyed to loading bins at the railway sidings.

The electrical equipment of the plant is of standard G.E.C. design and includes 16 motors of both the slip-ring and squirrel cage types ranging from 2 h.p. to 100 h.p. All motors are 3-phase, totally enclosed, dust and waterproof and fan cooled where necessary.

Fig. 33 shows a continuous lead casting machine installed recently at the Ellesmere Port Works of the

Associated Ethyl Co., Ltd. The machine, with an overall length of 32 ft. 3 in., has a capacity of 10 tons of lead pigs an hour. Eighty-eight moulds form the basis of the machine, each mould having a capacity of 1 cwt. in two 56 lb. pigs. The moulds, each of which travels upon four bushed track rollers, are arranged to travel around the track and are not connected with one another. At the driving and discharge ends retaining rails are fitted on the outside radius to accommodate the moulds around the track.

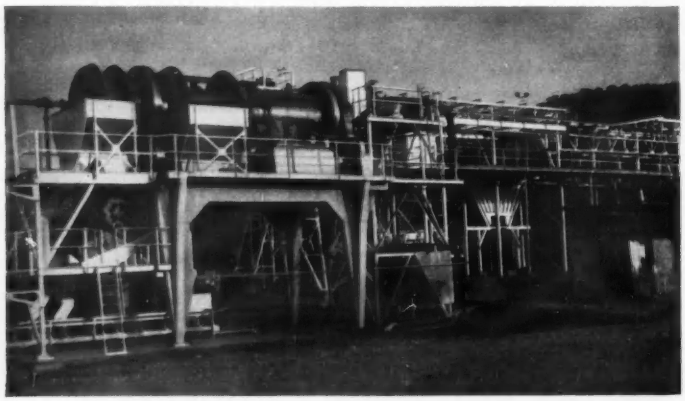


*Fig. 32.—The scrubber and screen in the washing section of the bauxite plant.*

Lead is poured at a temperature of 400/420 deg. C. and a running speed of 2·52 ft. per minute facilitates the necessary cooling which, together with contraction, assists ejection at the discharge end. After discharge, the moulds return by gravity along the lower track to the feed end. Drive is by means of a 5 h.p. motor driving two double reduction gears in a reduction box which in turn drive a sprocket. The teeth of this drive sprocket engage with the bushed track rollers at the drive end and traverse them around the inner radius of the slide rails, the drive being transmitted by each mould pushing against the preceding one.

A dust collecting plant has been installed at the Askern Works of Doncaster Coalite, Ltd. The plant comprises two 27 in. inlet dia. Micron precipitators connected in parallel with a fan which is directly driven by a 75 h.p. slipring motor. The plant handles between 20,000 and 26,000 cu. ft. of gas per minute from a coal dryer at temperatures between 45 deg. C. and 65 deg. C. and precipitates between 50 and 400 lb. of coal dust per hour. The dust which would otherwise be discharged to atmosphere is returned through the system and used in the works.

The largest single roller crusher to be built at Erith, a 30 in. dia. by 60 in. long machine, was commissioned at a cement plant in Rawang in the Federation of Malaya. The machine is driven by a 175 h.p. motor and has a capacity of 120 tons of limestone an hour and reduces 30 in. pieces to a minus 6 in. product. The crusher is of sectionalised cast steel construction and weighs over 40 tons.

Fifteen conical ball and pebble mills were completed during the year, eight of which were for export. The Selection Trust, Ltd., ordered four 10 ft. by 72 in. ball mills for their Mufulira Mine and two 10 ft. by 72 in. mills for Chibuluma. The mills are equipped with 33 in. by 16 in. ball and socket trunnion bearings, a 6 ft. radius scoop feeder and are driven through single helical gears. Manganese steel body-liners are fitted and a typical duty is to grind copper ore to 65 per cent. minus 200 mesh at the rate of 750 tons per 24 hours.

**MATERIALS HANDLING EQUIPMENT.**

A significant feature of the development work undertaken during the year has been the design of a 5-inch idler as an addition to the existing range. It is proposed to manufacture this for standard belt widths from 18 inches upwards. Since the idler is a fundamental detail of all conveying equipment con-

*Fig. 33.—Continuous lead casting machine at Ellesmere Port.*

siderable attention has been paid to the details of its design, particularly in regard to grease sealing and manufacturing cost.

After modifications in the development stage, a batch of idlers of the new design was manufactured in the Works and these are now undergoing exhaustive field tests, where they are being subjected to arduous duties, such as handling large capacities at loading and bend points under exposed conditions. During these trials records will be kept of performance in order to ensure that, once the design is proved, the new idlers shall be efficient and reliable in every way.

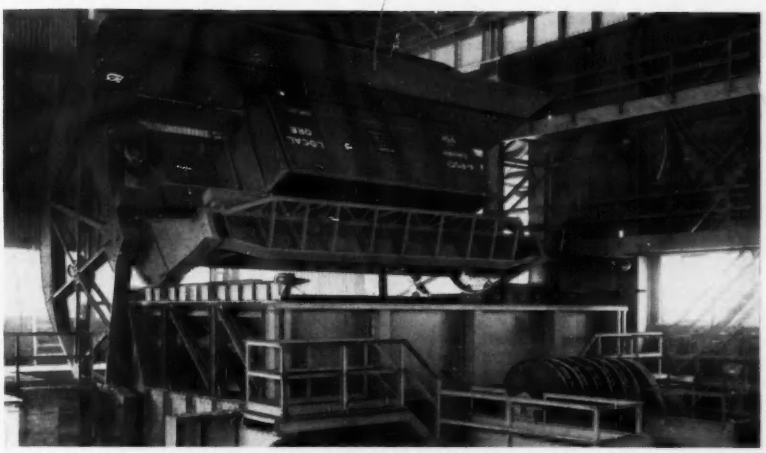


*Fig. 34.—60-ton wagon tippler at the Appleby-Frodingham Iron and Steel Works, Scunthorpe.*

Additional design work has taken place on modifications to the larger wagon tipplers, which will reduce the amount of structural steel involved in the building of these machines, and in consequence will also reduce their weight. New methods of operation are also incorporated.

Two plants of particular note, including extensive material handling equipment, have gone into operation during the period under review.

The first of these is the "Seraphim" project of the Applcby-Frodingham Steel Company at Scunthorpe, where the initial plant was installed by Fraser & Chalmers in 1924 for the blending of local ores. Various extensions have been made to this plant, culminating in the handling system for the remarkable "Seraphim" project. These comprise belt conveyors of varying widths to a total length of 17,000 ft. which include the interconnecting conveyors in enclosed steel bridges between the new crushing plant, new sinter plant and the existing installation, also the conveyors in the crusher and sinter plants proper and the coke handling equipment.

Besides the conveyors, a 60-ton capacity wagon tippler (fig. 34), batteries of Gyrex screens, six Pennsylvania Dixie mills and numerous Sherwen feeders are incorporated in the plant as a whole.

The second interesting plant, which is now partially in operation, is the ore handling and preparation plant which has been supplied to the Kapitalna Ironworks at Zenica, Yugoslavia, to the order of Invest-Import, Belgrade (fig. 35).

This plant commences at the receiving station for rail-borne ore and comprises the conveying, primary and secondary crushing and screening sections of a very comprehensive nature. Beyond this there are intermediate and fine crushing and screening sections. The plant is operated by G.E.C. motors and switchgear, the control being so arranged that conveyors, crushers and screens can be started in one of a number of sequences, according to the route and process for

*Fig. 35.—Ore preparation plant at the Kapitalna Iron Works, Zenica, Yugoslavia, in course of erection.*

the ore being handled at any particular time. This plant is peculiar in that 80 per cent. of the ore used is intended to be crushed down to 3 mm. ($\frac{1}{8}$ in.) for sintering purposes, and represents one of the largest plants known for this duty.

Further additions have been completed to the coal handling plant at the Barking Power Station of the British Electricity Authority, increasing the coal storage capacity of this station by a quarter of a million tons. The plant is noteworthy in that the main conveyor to the new storage ground is over 1,200 ft. long and is reversible, so that not only may coal be stocked by this conveyor, but is reclaimed by the same conveyor.

Manufacture is proceeding of an ore preparation plant for Aviles in Northern Spain, including a four-bed blending and reclaiming system.

In course of manufacture also is an ore handling and screening plant for Colvilles, Ltd. at their Clyde Iron Works, where the main ore handling plant was supplied some years ago.

Conveyors and side-discharge tipplers are also under construction for a number of coal handling plants for the British Electricity Authority.

It is worthy of mention that conveyors in connection with coal washing plants for the National Coal Board are not inconsiderable, 62 conveyors being under construction for this purpose, as well as several standard 35-ton side-discharge wagon tipplers.

**SHERWEN ELECTRO-MAGNETIC VIBRATING EQUIPMENT.**

Development has concentrated on the extension to existing ranges of Sherwen feeders and conveyors, and several new standard machines have been added.

The new flameproof vibrator, now operating feeders in collieries below ground, has proved most successful. The latest development of this type of feeder is an all-steel fabricated vibrating conveyor with a new system of springing and powered by a new design push/pull single vibrator. This machine is a development from the multiple vibrator type.

Two of these new type conveyors (fig. 36), 20 ft. long by 4 ft. wide are operating at the " Seraphim " project of the Appleby-Frodingham Steel Company's works beneath the blast furnace coke track hoppers, and are responsible for feeding the incoming coke to the blast furnace conveyors.

A new immersion type bunker vibrator has proved highly successful in concrete bunkers, particularly at power stations, and some hundreds of these have been ordered by the British Electricity Authority. This type of machine is of considerable advantage in such places as power stations where the risk of fatal accidents to personnel entering bunkers to clear stoppages is quite high ; this risk is now obviated by the use of these new vibrators.

An additional interesting application has been the installation of a totally enclosed 8 ft. by 4 ft. single deck screen aboard The Tarakohe Shipping Company's vessel Golden Bay. This screen separates refuse from bulk cement prior to unloading.

*Fig. 36.—Sherwen vibrating conveyor at the Appleby-Frodingham Steel Company.*

# Coal Preparation Plant

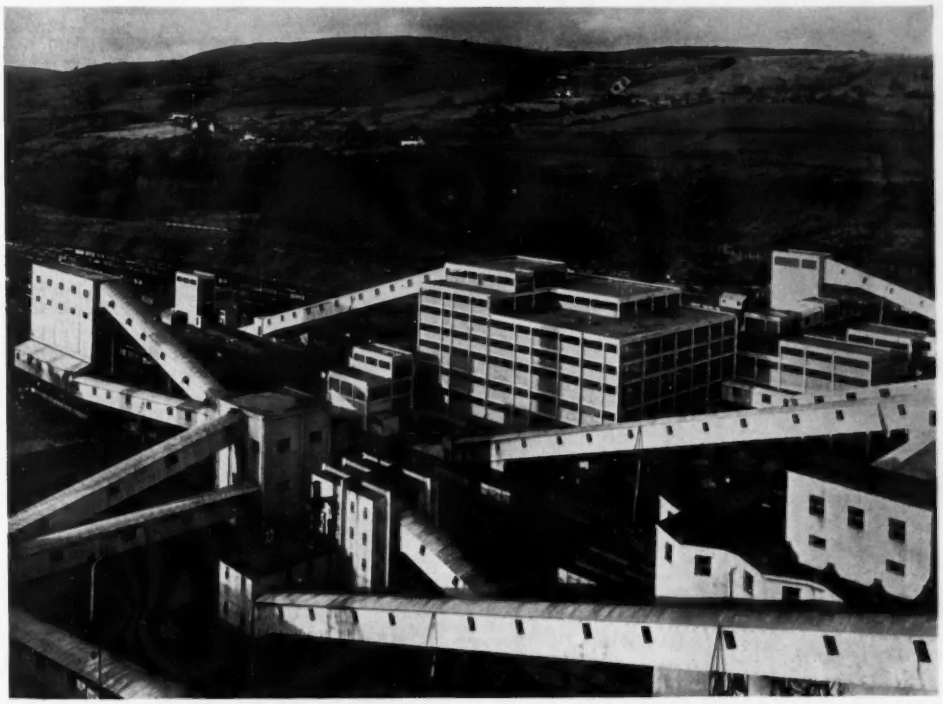


*Fig. 37.—General view of the coal preparation plant at Nantgarw.*

Orders received for coal preparation plant from the South Western Division of the National Coal Board comprise an installation for Maesteg which will serve as a central washery for four pits. The contract includes a Chance cone 12 ft. diameter, which will be suitable for producing three products : clean coal, middlings and refuse. In the initial stages the plant will treat 8 in. × 1½ in. coal and provision will be made so that the Chance section can be adapted to clean 8 in. to $\frac{1}{16}$ in. coal and a Fraser & Chalmers froth flotation plant will be added to deal with material below $\frac{1}{16}$ in. in size. The total capacity of this plant will be 250 tons an hour and, in addition to the washing equipment, the contract includes belt conveyors, the steel frame building, electric motors and control gear, civil engineering work, lighting, power wiring and heating.

A further Chance coal preparation plant has been ordered for the Onllwyn group of collieries in the No. 9 area which will have a capacity of 150 tons an hour. A 10 ft. dia. Chance cone is included which will treat raw coal between 5 in. and $\frac{5}{8}$ in. in size. Included in the contract, in addition to the washery equipment, are pumps, crushers, belt conveyors, the electrical equipment and steel frame building. The Chance cone will be arranged for three-product separation.

Plants commissioned during the period under review include those at Nantgarw, South Wales, which has an installed capacity of 350 tons an hour, provision having been made to extend the duty to a capacity of 700 tons an hour. This plant is of interest in that it includes the first froth flotation plant manufactured by Fraser & Chalmers to work in conjunction with the Chance process so that the whole of the run-of-mine coal is cleaned in no more than two processes, thus simplifying plant operation and reducing capital cost. Fig. 37 shows the plant from the exterior and fig. 38 shows a bank of Fraser & Chalmers froth flotation cells. The capacity of the fines cleaning section (for $\frac{1}{16}$ in. × 0 in.) is 60 tons an hour, and for this duty three banks of cells have been installed.

Shortly after the plant was commissioned an acceptance test was made in conjunction with the National Coal Board and the results obtained, both on the Chance section and the froth flotation plant, were comfortably within the guarantee figures.

A coal preparation plant with a capacity of 50 tons an hour has been commissioned at Newlands Colliery in South Wales for treating coal between 6 in. and 1½ in. In Australia, the plant installed for the Corrimal Coal & Coke Pty. Ltd., of Sydney, has also been put into operation. The capacity of this plant is 200 tons an hour and the equipment

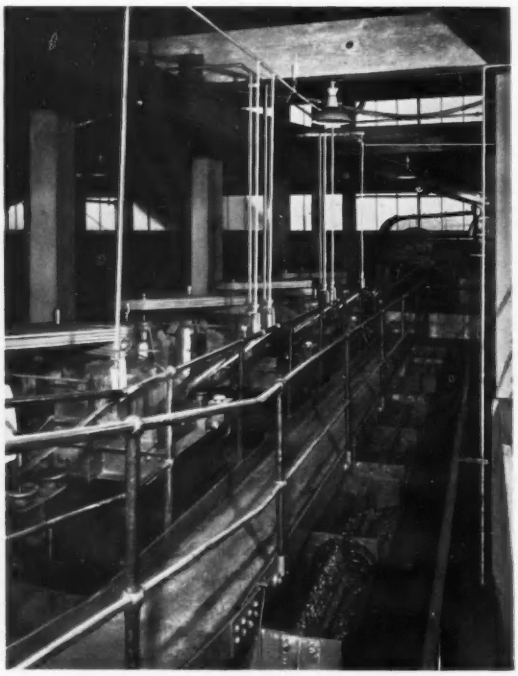


*Fig. 38.—Bank of froth flotation cells at Nantgarw.*

includes a 10 ft. dia. Chance cone for two product separation: clean coal and refuse. Corrimal, near Port Kembla, some 40 miles from Sydney, New South Wales, is the first Fraser & Chalmers Chance coal preparation plant to be installed in Australia.

In addition to the contracts already mentioned, two smaller orders have been received. These are for the addition of middlings extraction equipment to two existing washeries, one at Blaengarw, the other at a Deep Duffryn, in South Wales. The plant at Blaengarw was laid out in the design stages so that middlings extraction equipment could be added later, which indicates the flexibility of the Chance process in that it can be modified relatively simply to meet changing conditions of the raw coal mine. Both extensions are due to go into operation early in 1955.

Brief reference was made in the last review of progress to an order received from the National Coal Board for coal preparation plant for Cwm Colliery in the No. 3 (Rhondda) area. It is now possible to give further details as regards the electrical equipment which includes the main transformers, switchgear, motors and cabling. In addition to the 13-panel main board, which is of the S.V.D. type, there are six distribution switchfuse boards and thirty-eight contactor boards of the cubicle type. The 175 motors involved range from ½ h.p. to 90 h.p. and represent a total of some 3,000 h.p. Much of the equipment is arranged for sequence control, while a master tripping scheme enables the whole of the equipment to be shut down in an emergency by the operation of any one of several stopping control buttons which are located at strategic points throughout the plant.

A machine of topical interest in coal preparation plant and gasworks plant is the Pennsylvania Bradford breaker. Eleven such machines are now on order: nine for the National Coal Board and two for Gas Boards.

Coal is fed through an inlet chute into the perforated barrel of the machine. Oversize, tramp iron, refuse and so forth are carried up the machine by shelves fitted to the inside of the drum, dislodged and, on falling to the bottom of the drum, are broken, in the case of coal, or continued along the drum in the case of refuse; thus coal is sized and refuse discharged at the other end of the machine.

Four Bradford breakers are to be installed at the Manvers coal preparation plant, three 9 ft. dia. by 19 ft. 6 in. long and one 9 ft. dia. by 17 ft. long. Fig. 39 shows one of the machines under construction. Since a large proportion of stone is expected to be dealt with by these machines they are specially strengthened to undertake this duty. The three larger machines will each deal with 500 tons an hour of run-of-mine coal to produce a minus 8 in. product. The smaller machine will deal with 60 tons an hour of hard middling. Running at 16 r.p.m. the machines are notable for the low power needed to drive them, each machine requiring only a 50 h.p. motor.

During the period under review two 9 ft. by 14 ft. roller mounted breakers have been put to work in a colliery in Northern France. Further machines of similar types and capacity have also been installed.

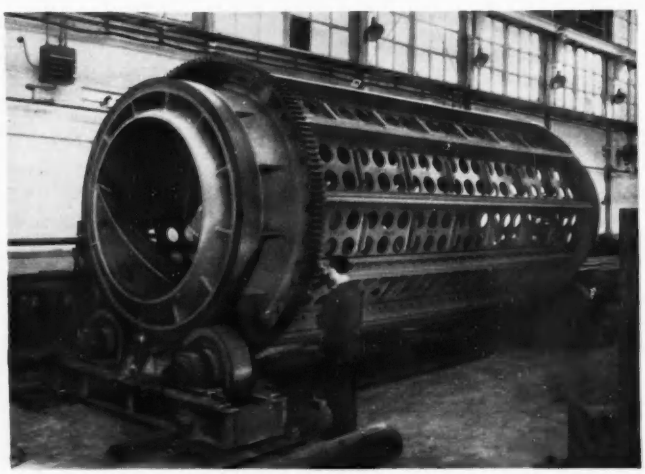


*Fig. 39.—One of four Bradford breakers for the Manvers coal preparation plant.*

# Rolling Mills

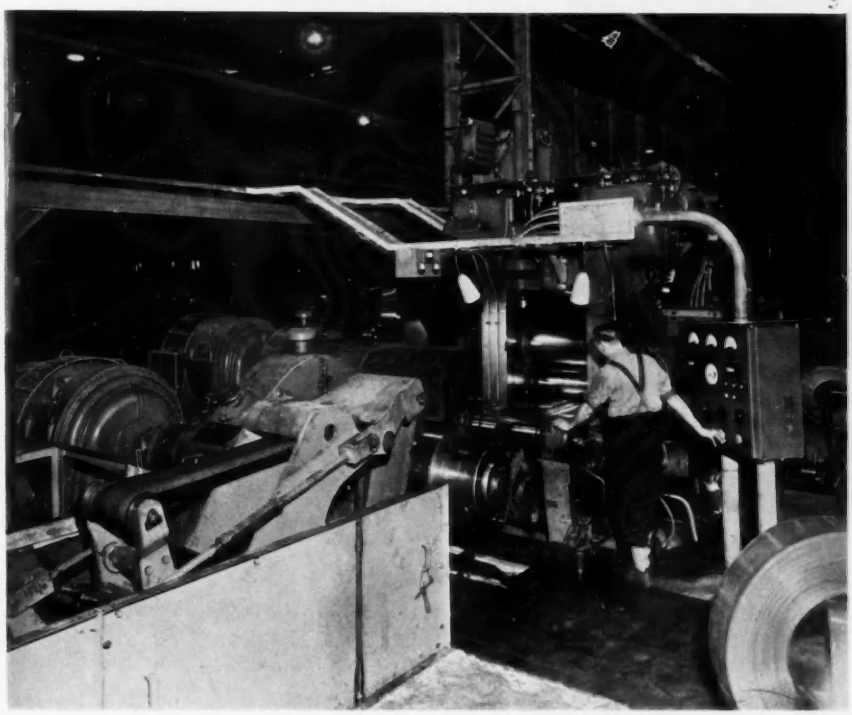


*Fig. 40.—24 in. skin pass mill at Whitehead Iron and Steel Co., Ltd.*

Some twenty-five years ago the G.E.C. installed the electric drive for a 3-stand Krupp mill at the Kynoch Works of Imperial Chemical Industries. This drive has recently been completely modernised and now embodies the control exciter system which has been installed with marked success at the Steel Company of Wales Abbey Works, Richard Thomas & Baldwins Works at Redbourn and, more recently for the skin pass mill at the Whitehead Iron & Steel Co., Ltd. (fig. 40). The original motors have been retained, and the generator fields have been reconnected to meet the more precise operation obtainable with control exciters. For the tension reel drive a new 100 h.p. motor and its associated motor generator set have been supplied.

A contract has been placed by Richard Thomas & Baldwins, Ltd. covering the conversion of the 3-stand strip mill at Ebbw Vale Works to a 4-stand mill (fig. 41). The electrical equipment for this mill was first brought into service in 1938. At present it is intended to retain the existing drives for the first two stands, so that the immediate output speed of the mill, when altered, will be 1,500 ft. per min. At a later date, when stands 1 and 2 are modernised, this speed will be increased to 2,000 ft. per min. The present contract covers two 3,000/4,000 h.p. twin-armature motors for driving stands 3 and 4, a 750/1,000 h.p. twin armature machine for the reel drive ; a 6-machine motor generator set driven by a 9,000 h.p., 11 kV synchronous motor, all the associated A.C. and D.C. switchgear, control board and mill control cabinets. Here again the G.E.C. control exciter system will be used.

A recent contract from the Steel Company of Wales covers all the electrical equipment for a 78 in. by $\frac{3}{8}$ in. cold cut-up line having maximum speeds of 250 ft. per min. of strip up to $\frac{3}{16}$ in. thick or 150 ft. per min. for $\frac{3}{8}$ in. strip. The line is designed to cut strip from 20-ton coils into lengths varying from 4 ft. to 36 ft. long and to pile the cut lengths. The electrical plant and switchgear include a 5-machine motor generator set driven by a 700 h.p., 3·3 kV induction motor ; nine force-ventilated D.C. motors totalling over 700 h.p., control exciters for the main motor generator set and for current control of the mandrel drive ; the main control board and various squirrel cage motors for driving shears and other auxiliaries.

A contract has been received from Dorman Long (Steel) Ltd., for all the electrical plant and control gear associated with the auxiliary drives of a combined

universal beam and heavy section mill for the new works at Lackenby. The contract includes fifty-nine mill-type motors totalling 5,850 h.p., ten motor-generator sets driven by synchronous motors which represent a further 5,950 h.p., control exciter sets and five contactor control boards. For all double motor drives, such as are being supplied for the screw-downs, working tables and the like, a series-sandwich connection of the motors and their associated generators is adopted. Fully interlocked interconnecting links are provided to meet the emergency conditions which would arise in the event of any one machine being out of service. All drives embody control exciters to provide rapid and precise response in motor speeds to correspond with the requirements of the mill at any instant.

A large amount of equipment is also being supplied in connection with the important expansion programme at their Cleveland Works. One contract covers the control of the screw-down and shear drives associated with No. 6 blooming mill and includes four 270 h.p. mill type motors ; a 6-machine motor generator set driven by a 900 h.p. 2,750 volt synchronous motor and a control exciter set. Three speeds, up or down, are provided for the screw-down motors, the top speed being obtained by field weakening of the motors and the other two speeds by varying the armature voltage of the machines by means of a pattern potentiometer. Forward and backward hand-inching control of the shear is provided in addition to the automatic cycle control, in which speeds are determined by a speed setting potentiometer. The control exciter system is used for both the screw-down and shear drives, while the arrangements for emergency operation are similar to those referred to above.

Another order for this steelworks includes all the control gear for a medium section mill for rolling a complete range of medium size structural sections. The mill consists of roughing, intermediate and finishing stands, each driven by an existing 1,500 h.p. motor and each supplied from a grid-controlled rectifier equipment. When starting the mill, the speeds of the three motors are controlled by bringing their respective rectifier voltages up to the working value. Subsequent speed variation is obtained by field control of the motors.

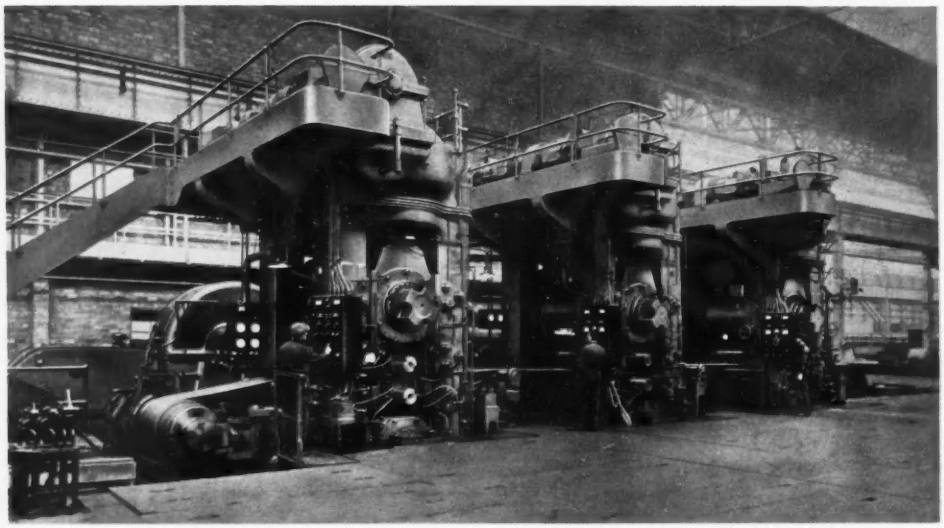


*Fig. 41.—3-stand strip mill at Richard Thomas & Baldwins, Ltd., Ebbw Vale, commissioned in 1938 and now being converted to a 4-stand mill.*

Link arrangements, similar in operation to those referred to above, enable any two rectifier equipments to operate in parallel and feed all three mill motors in an emergency. In addition to the foregoing, over one hundred A.C. mill type motors of 85 h.p. and 35 h.p., totalling over 7,600 h.p. are on order for the Cleveland Works.

Electrical equipment is on order for a pickling line in the Shotton Works of John Summers & Sons, Ltd. and includes two 550 h.p. and two 50 h.p. D.C. motors together with a 1,400 h.p. 4-machine motor generator and all associated control gear.

A 500 h.p. mill motor is also being supplied for driving a 10½ in. double-duo steel rolling mill at the works of Kayser Ellison & Co., Ltd. The motor is supplied from a 413 kW rectifier equipment ; the contract also covers four auxiliary A.C. machines and all relevant control gear.

For the Australian Iron and Steel Co., Ltd., Port Kembla, a 1,400 h.p. D.C. motor is being supplied to drive an existing mill, and here again control exciters are being used.

# Industrial Electrification

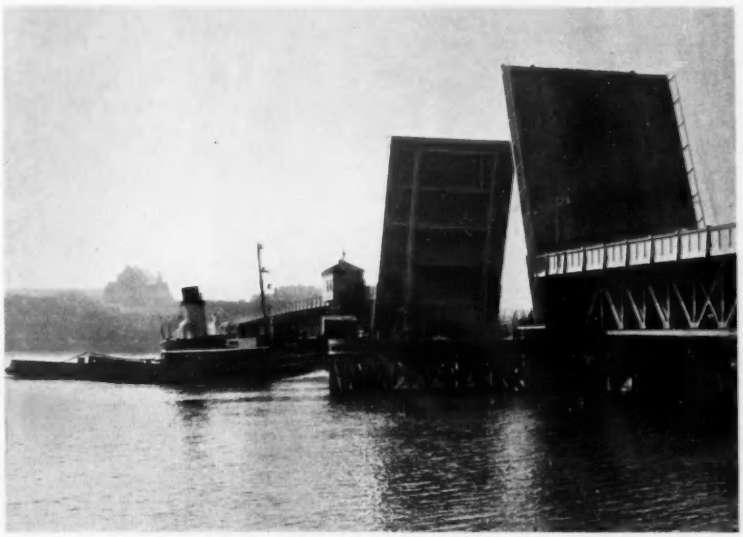


*Fig. 42.—The Jubilee Bridge at Barrow-in-Furness.*

**BRIDGE CONTROL.**

The Jubilee Bridge at Barrow-in-Furness, fig. 42, was officially reopened several months ago after being modernised. In connection with the operating mechanism of the double bascule opening span, all the electrical drives and cabling were replaced and a new Ward-Leonard system of control installed. The sequence of operations for raising or lowering the bridge is fully automatic and under the control of a single handwheel. Each leaf is powered by a 25 h.p. D.C. motor of the totally enclosed type. The motors are mounted inside the leaves and each is supplied through flexible cable from its own 35 h.p. Ward-Leonard motor generator set. A stand-by motor, provided on each leaf, may be connected in circuit by a changeover switch incorporated in the control gear. As soon as the sequence of operation for opening the bridge is initiated, road traffic is warned automatically by red lights and bells, while shipping in the channel is informed of the position of the opening span by solenoid-operated semaphores. Four white navigation lights, two facing upstream and two downstream, indicate the extremities of the bridge opening. These lights are switched on automatically at night.

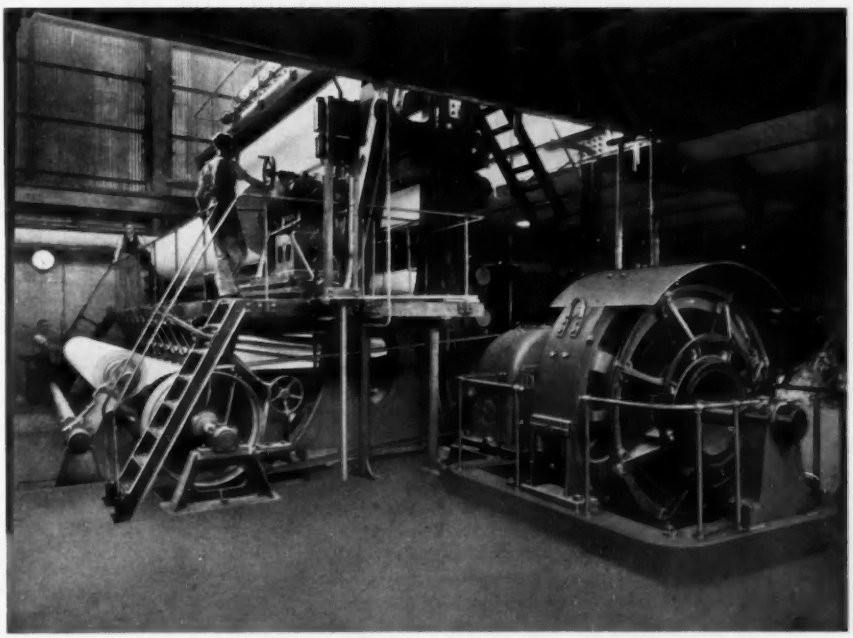


*Fig. 43.—250/500 h.p. D.C. motor driving a super-calender in the Aylesford Paper Mills of A. E. Reed & Co., Ltd.*

## GEAR TESTING EQUIPMENT.

Following upon the satisfactory performance of gear testing equipment supplied some years ago, the Rover Co., Ltd., have placed a further order. The equipment now being supplied comprises a 0/50 h.p. motor for driving the gearbox, a 0/45 kW loading generator, a 60 h.p. motor generator set for supplying the losses and a main control desk with a metering and indicating panel.

The test rig and control gear are housed in a sound-proof room, the motor generator set, the driving and loading machines being outside. Facilities are provided for the operator to accelerate the gear drive from rest to full speed at maximum torque ; reduce power from maximum to zero at full speed ; reverse the torque and increase the power from zero to maximum at full speed (overdrive) and to slow down from full speed to rest at maximum reverse torque (overdrive).

By adjusting the basic speed of the loading generator relative to that of the motor driving the gear box, allowance can be made for the different gear ratios. The equipment may be held steady at any desired set of operating conditions while the gear noise level, power and speed readings are recorded.

*Fig. 45.—Witton Kramer 65 in. deep penetration magnet.*

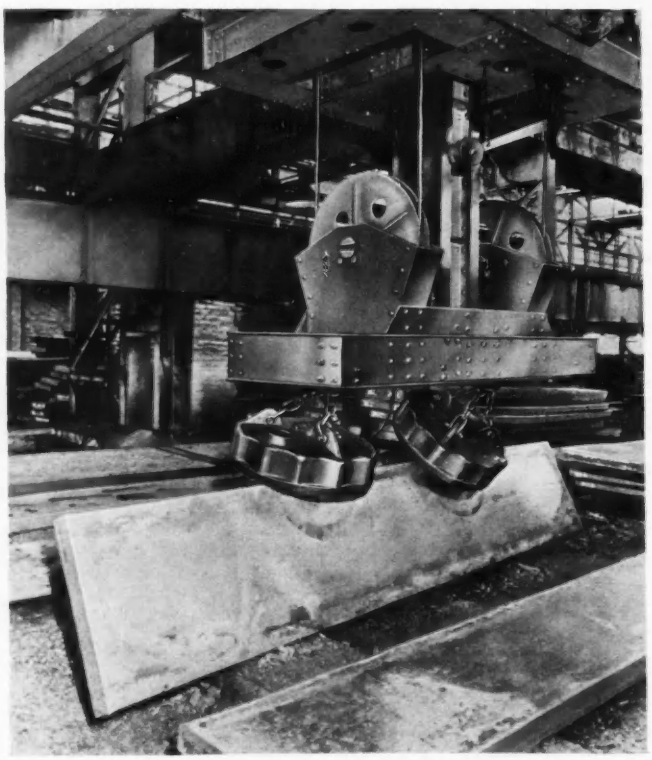


*Fig. 44.—A pair of 36 in. diameter magnets turning 5-ton slabs in the slab yard of the Abbey Works of the Steel Company of Wales.*

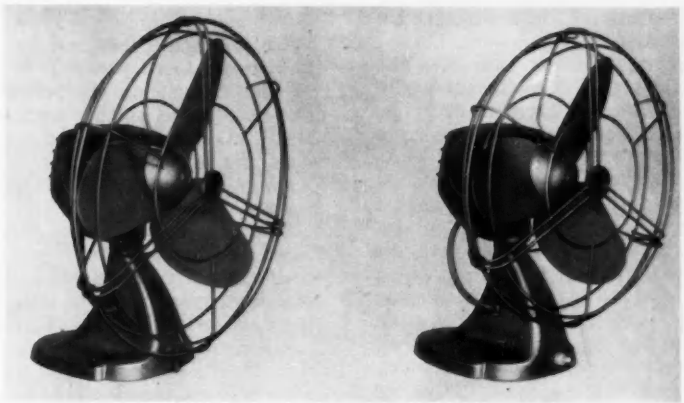


*Fig. 46.—New 12 in. and 10 in. oscillating table fans.*

PAPER MILL EQUIPMENT.

Testimony to the satisfactory performance of a super-calender drive which was supplied some twenty-two years ago to A. E. Reed & Co., Ltd., is afforded by the repeat order recently placed for a similar equipment. The new equipment comprises a 225/550 h.p. main driving motor with all associated control gear to provide 32 equal steps of acceleration and retardation, both of which are under the control of a multi-contact motor-driven regulating switch. A motor-operated shunt field regulator gives a 2 : 1 range from base speed, while 3-step dynamic braking control is included for emergency stopping. Operation is by push buttons at the drive itself and on the remote switchboard, while indicating lamps show whether operation is set for "crawl" or full-speed conditions. The earlier equipment which continues to give full satisfaction is shown in fig. 43.

*Fig. 47.—Fractional horsepower capacitor start motor.*

CONTROL EQUIPMENT.

If the maximum advantages are to be derived from remote control schemes, all the control switches must be within easy reach of the operator; this has given rise to a demand for a compact control switch. Such a switch has been developed and is suitable for mounting on $1\frac{5}{32}$ in. horizontal and 6 in. vertical centres. The body and many of the individual components are precision mouldings so that the assembly can be varied to satisfy a variety of functions. By means of a four-sided cam plate the control switch can be arranged as a simple two-way changeover switch with or without spring return to "off", a changeover switch without a central "off" position or a changeover switch with spring return from top or bottom position only, as desired.

MAGNETS.

Throughout the past twelve months, orders for lifting magnets and separator magnets have been well maintained. One of the more interesting applications is to be found in the slab yard at the Steel Company of Wales where an equipment comprising two 36 in. magnets is in service for turning 5-ton slabs (fig. 44).

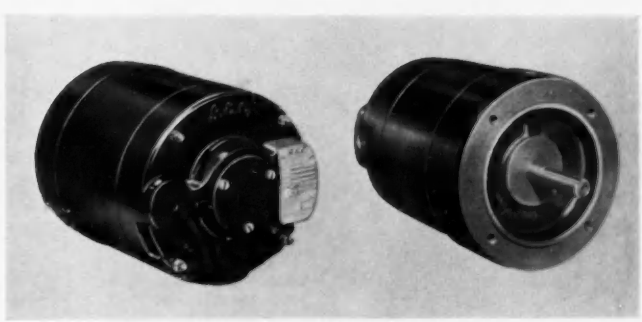


*Fig. 48.—Flange mounted type fractional horsepower motor.*

The satisfactory performance of these magnets has resulted in a repeat order.

Small magnets arranged in cluster form have also been supplied for handling coils. A similar equipment is in hand for Vauxhall Motors for export to Australia.

The range of lifting magnets has been extended to include deep penetration magnets of 56 in. and 65 in. dia. (fig. 45). These magnets are specially built to meet the demand for greater lifting capacities and for very heavy duties such as are encountered in slag reclamation. An 8-section copper strip coil is used, the space between the coil and the shell being filled with a high melting point compound to render the magnet weatherproof. Between each section of the coil is an insulating washer consisting of micanite sandwiched under pressure between two layers of asbestos which prevents disintegration or flaking of the mica. The pole shoes are made from Cromax alloy steel which combines the required magnetic properties with particularly good wearing qualities. Provision is also made for accommodating a non-linear resistor which is permanently connected in parallel with the magnet coil and thus serves to limit the voltage rise in the event of a break in the cable between the magnet and its control gear.

### FANS.

During the year two new oscillating table fans (fig. 46) have been developed for use on A.C., thus completing a range of modern table and bracket fans. The new fans are 10 in. and 12 in. models fitted with metal blades and guards and, in appearance, follow the same pleasing outline as the well-established 8 in., 10 in. and 12 in. rubber bladed fans.

The 10 in. fan is provided with an on/off switch; the 12 in. fan has a two-speed and off-position regulator mounted in the base. Both fans incorporate the friction clutch device which is now common throughout the entire range of oscillating table fans. These fans can be obtained in two attractive colours: metallic blue or pale bronze.

### FRACTIONAL HORSEPOWER MOTORS.

A new range of fractional horsepower A.C. motors has been produced, similar in appearance to the existing designs but more compact and lighter in weight. The new motors comply with British Standard No. 2048: 1953 which lays down standard dimensions for two frame sizes of general purpose fractional horsepower motors of the foot-, resilient- or flange-mounted types, with sleeve or ball bearings. The new range is thus mechanically interchangeable with other makes complying with this specification. It is of importance to note that, with the exception of the flange-mounted motors, they are also interchangeable with American motors built to the N.E.M.A. Fractional Horsepower Standard MG2-1951 for general purpose motors. Figs. 47 and 48 show respectively a capacitor start motor and a flange-mounted motor.

### INDUSTRIAL BATTERY CHARGERS.

A new range of single circuit industrial battery chargers, which will replace the existing range, is now in course of production. The charging capacities of the equipments in the new range vary between 12 cells at $2\frac{1}{2}$ amp. and 36 cells at 20 amp. and comprise, in all, nine different ratings to meet all requirements. The largest and intermediate sizes of the new chargers are shown in figs. 49 and 50 respectively, and it will be seen that a common instrument panel is used in the larger sizes; this and other common components have been introduced to achieve a large measure of standardisation and interchangeability of spares throughout the range. The new chargers will be available during the first quarter of 1955.

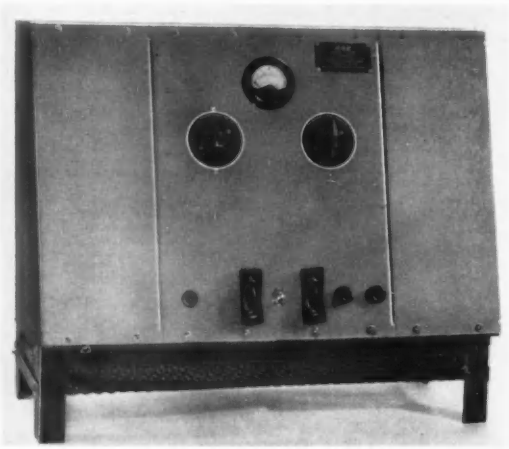


*Fig. 49.—Battery charger to charge 36 cells at 20 amp.*

*Fig. 50.—Intermediate size battery charger.*

# Transport

*Fig. 51.—Manchester-Glossop railway electrification.*

**RAILWAY ELECTRIFICATION.**

Since the official opening of the electrified line between Manchester and Glossop last June, the performance of the multiple unit trains has given every satisfaction. For this rolling-stock the G.E.C. supplied all the electrical equipment, a full description being given in an earlier number of this Journal.* A six-car train in Glossop Station is shown in fig. 51.

A contract now placed for similar equipment comes from the Eastern Region of British Railways in connection with the electrification of the line between Shenfield and Southend. It will be recalled that electrification of the section from Liverpool Street to Shenfield was completed some 3 years ago, and that some 30,000 kW of rectifiers with associated 33 kV A.C. and 1,500 volt D.C. switchgear was supplied. The new order for rolling-stock covers the complete electrical equipment, including motors and control gear for thirty-two 4-coach trains.

Work on the manufacture of the electrical equipment for fifteen diesel-electric shunting locomotives is in an advanced stage and erection on the locomotives has begun. Brief details of these locomotives which are also for British Railways were given in the progress review last year.

The repeat order received from Tranvia Electrico de Pontevedra, Spain, for electrical equipment for three trolley buses, has been fulfilled. Each is driven by a 95 h.p., 500 volt motor on a one-hour rating. The master controller is of the butt contact type and rheostatic braking is provided using a scheme patented by the G.E.C.*

A problem which continually faces the traction control engineer is that of reducing the size of the control equipment. For certain types of low floor coaches it is practically impossible to accommodate the orthodox unit switch type of control. To meet these conditions of space restriction, a camshaft control equipment has been developed and an experimental unit (figs. 52 and 53) is now undergoing trials on the London Transport Executive services.

The camshaft control group operates on the electro-pneumatic principle and includes the line switches, reverser, motor combination control unit, resistance and field strength control unit, in addition to overload, accelerating and no-current relays. Such an equipment is smaller and lighter than the established designs and may offer the only solution for low floor coaches with severe limitation of space. This camshaft control equipment has been designed with a view to making it suitable for many applications from the simple subway coach to trains requiring semi-multi notch control and considerable field control. It embodies an acceleration control which operates on the escapement principle with no extraneous damping.

* "Manchester-Glossop Railway Electrification" by E. H. CROFT, *G.E.C. Journal*, Vol. XXI, No. 3, July, 1954.

* British Patent No. 616679.

PLUG-IN RELAY TEST STAND.

A specially designed test stand for servicing the whole range of their plug-in relay equipment has recently been introduced by The Siemens and General Electric Railway Signal Company Ltd. (fig. 54.)

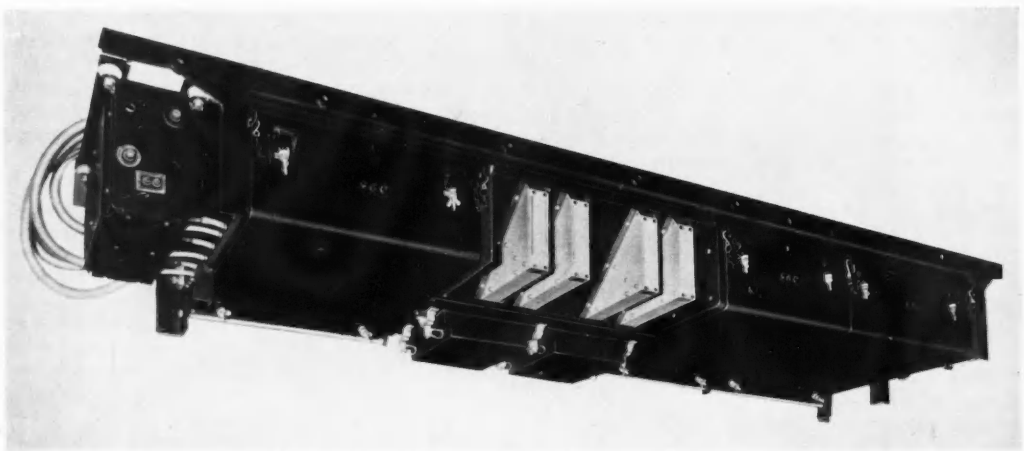


*Fig. 52.—Camshaft control equipment with covers in position.*

The first of these test stands has already been supplied to the Toronto Transit Commission for servicing relays supplied for the Rapid Transit Subway signalling system.

The relay to be tested is centrally mounted at eye level and an adjustable inspection lamp enables all parts to be adequately illuminated without glare.

ium and is fitted with standard moulded plug and socket members which fulfil the requirements of making connection with the test stand circuits and providing the plug-in mounting for the relay it is designed to take. Thus the relay under test jacks into the adaptor and locks by its catch in exactly the same manner as it is plugged in when in service.

A further advantage of the adaptor base method is that those units which have internal adjustments brought out to base can be suitably connected by terminals on the adaptor. For example, cross-strapping terminals are provided on the adaptor for pulsing-

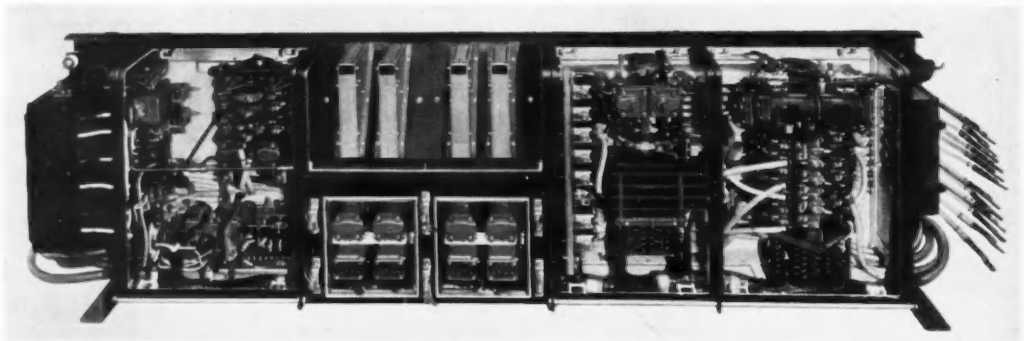


*Fig. 53.—Experimental camshaft control equipment, viewed from below, with covers removed.*

To make it possible to bring a wide range of relays to one control position and to ensure that the relevant supplies, meters and controls are properly connected, an adaptor base is provided for each type of relay. Each adaptor base plugs into the same central multi-socketed positions and is secured by dowel pins and wing nuts. It is constructed of high-grade cast alumin-

relay units for varying the number of pulses per minute and also for selecting the desired delay period for the time delay relays. By making cross connections on the adaptor base in the same way that strappings are made on the relay rack terminals, the site conditions can be reproduced.

To assist in the viewing of the contact closure indica-

tions and to identify every contact of a particular relay with its corresponding number on the selector switches when contact resistance tests are being made, an appropriate masking plate is provided for each type of relay. The plates are fixed by thumb screws to the movable

*Fig. 54.—Test stand for plug-in relays.*

lamp box and only those lamps concerned with the relay under test are displayed.

Certain of the plates carry information concerning cross connections that must be made to obtain different effects, for example, on a 0-30 seconds time relay the required time strappings are listed to enable the tester to check immediately if the correct terminals on the relay are bridged.

MARINE ELECTRICAL EQUIPMENT.

The liners Arcadia, Iberia, Bendigo and Ballarat of the P. & O. Steam Navigation Co., Ltd. are now in service. In addition to other G.E.C. equipment, all these ships employ extensive plural starting gear, the first two ships having 23-panel boards, the two latter 10-panel boards.

Main, emergency and group starter boards, totalling 100 panels for each ship, are in hand for A.C. vessels which are being built by the Furness Shipbuilding Co., Ltd., and Swan Hunter & Wigham Richardson, two for the Iron Ore Transport Company, Ltd., of Canada, and one for S. Ugelstads Rederi A/S, Norway. Additional electrical equipment includes turbo-alternator sets and engine room auxiliaries. For tankers building in Holland, eight 400 kW, 60 cycle alternators have been delivered, while for the Admiralty a heavy programme is in hand covering D.C. generators, alternators, motors, starters and transformers.

The 18,000 ton tankers Hyria and Hemiglypta for Shell Tankers, Ltd. and the 32,000 ton tanker Melika for the Gulf Oil Co., Ltd. have gone into service. These three ships are completely equipped with A.C. auxiliaries supplied by the Company. The Hemiglypta has, among other G.E.C. equipment, the first of the new three-oven ranges, many of which are being manufactured for future ships for the same owners. The ranges (fig. 55) are designed for operation on a 440 volt A.C. supply and are provided with thermostatic oven control and " Simmerstat " control of the hotplates.

In addition to the plural starting boards already mentioned, the liners Arcadia and Iberia carry much other equipment designed and built by the Company. The 600-line manual telephone exchanges, luminous call, fire alarm and lighting installations are particularly noteworthy. Fig. 56 shows the first-class lounge in the Arcadia, illuminated by Osram cold cathode tubes in indirect cornices, specially designed floor standards providing a tasteful addition. The Arcadia is the first ship in which three light sources : cold cathode, hot cathode and tungsten lamps, have been used on an extensive scale. The innovation has proved extremely pleasing and successful. The sister ship Iberia follows the general pattern of the Arcadia but is the first large passenger liner to be fitted with the new Deluxe Warm White Osram fluorescent tubes.

In collaboration with the decorative architects, the Company was responsible for the lighting of the State Apartments in H.M. Yacht Britannia, and also planned

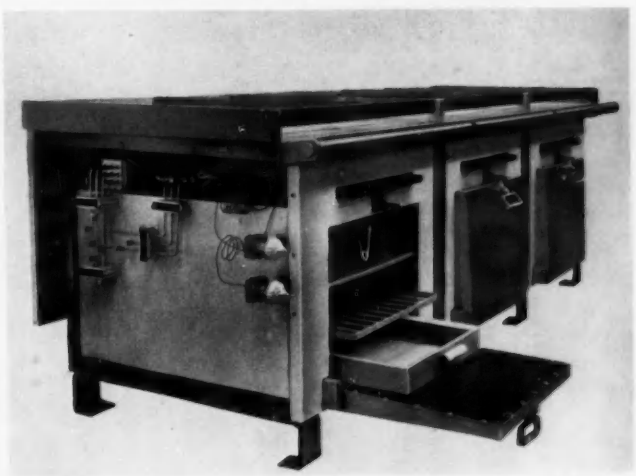


*Fig. 55.—Three-oven range for operation on 440 volts A.C., with end cover removed.*

and supplied the floodlighting for the funnel, superstructure, masts and flags. The 100-line cordless manual telephone switchboard (fig. 57) of novel design was supplied to the ship together with the associated instruments.

With the increasing use of alternating current on board ship at the standardised frequency of 60 cycles, a demand has arisen for frequency changers to convert the normal 50 cycle dock system to 60 cycles in order to provide shore-to-ship power supplies. Two stationary equipments, each rated at 300 kVA, are in service and a third is on order, while six of ten mobile equipments, also rated at 300 kVA, which are being supplied for service at naval dockyards, have been delivered. One of these sets is seen in fig. 58.

The Karachi graving dock is now in service. For this dock the electrical equipment comprises four 110 h.p. vertical spindle motors, several totally enclosed squirrel cage motors, together with the associated switch and control gear. Also in hand is the electrical equipment for a graving dock for the Dublin Port and Docks Board, for which over 1,000 h.p. of motors, with contactor control gear, are being supplied.

A further contract with Gwynnes Pumps, Ltd. has recently been concluded for the electrical plant and switchgear for the Singapore Harbour Graving Dock. The main pump motors are of the synchronous induction type, rated at 400 h.p. 3,150 volts, 333 r.p.m. Slipring motors, rated at 266 h.p. and 110 h.p., drive the drainage and fire pumps respectively.

*Fig. 57.—100-line cordless manual telephone switchboard.*

*Fig. 56.—Illumination of the first-class lounge in the Arcadia.*

The incoming high voltage supply and the feeders to the contactor boards for the main pump motors are controlled by a three-panel metalclad switchboard. All other machines are operated from a group starter board, arrangements being made for centralised control of the dock from a control desk.

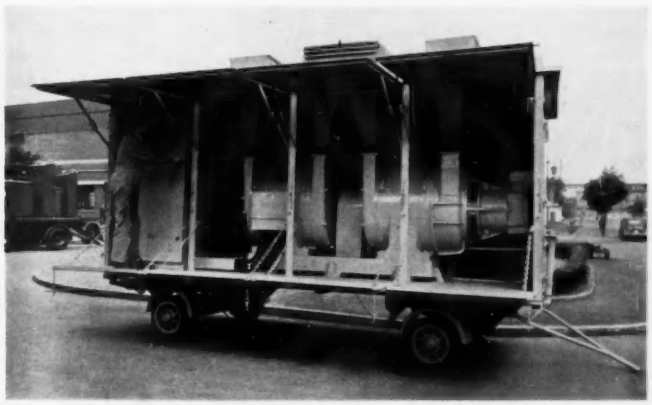


*Fig. 58.—300 kVA, 50/60 cycle mobile frequency changer.*

For the conversion of the electrical supplies at King George Dock, Hull, from D.C. to A.C. a large amount of transformers and switchgear is being supplied. The equipment includes two 1,000 kVA and six 500 kVA transformers which step down the 6·6 kV supply to 415 volts, 8-panel and 15-panel high voltage switchboards and four 415 volt air break boards.

Another contract recently placed for dockside equipment has been received from the Admiralty in connection with plans for the modernisation of Portland Dockyard. The complete scheme will involve the construction of eleven substations. Orders so far placed cover the first two of these as well as two 11 kV metalclad switchboards rated at 250 MVA.

**AERONAUTICAL EQUIPMENT.**

The Aeronautical Department has, over a considerable period, made a particular study of the design and manufacture of catering equipment for use in aircraft. As a result, the Company has produced a very comprehensive range of this type of specialised equipment which includes fan-circulated ovens, food and liquid beverage containers, urns, hotcupboards, grill boilers and so forth. These appliances are now installed as standard equipment on aircraft operated by the British Overseas Airways Corporation, British European Airways, Trans-Canada Airlines and Trans-World Airlines. In addition, they are also used by many non-scheduled airlines, such as the various charter companies.

As weight is naturally of the first importance in connection with any equipment used in aircraft, the Company has given particular attention to this most important requirement, and accordingly all the equipment produced for this service is built down to as light a weight as possible commensurate with performance. Every item has been approved by the Aeronautical Inspection Directorate and the Air Registration Board.

British European Airways recently approached the Aeronautical Department with a request that they should produce a rapid water boiler for service in the galleys of aircraft, the purpose being to have available, almost continuously, an ample supply of boiling water for making tea, coffee and other hot beverages. As a result of these negotiations with the Corporation, the G.E.C. produced the rapid water boiler referred to above (fig. 59). The rating of the boiler is 5 kW at 28 volts D.C., with a normal capacity of 8 pints. It is fitted with an automatic cut-out device to safeguard the element in case it should boil dry, and has a control switch and warning light which gives an indication that the unit is switched on. The inlet pipe is fitted with a non-return valve for hand pump operation and there is a pressure and overflow pipe. The element is of an extremely robust sheathed wire immersion type.

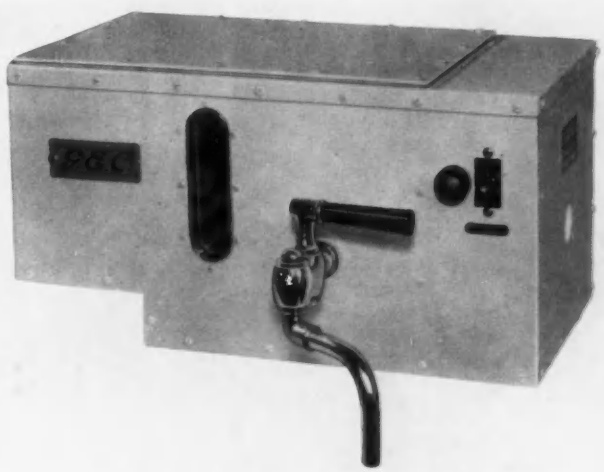


*Fig. 59.—New rapid water boiler for use in aircraft.*

# Electronic Control

## PRINTING PRESS CONTROL.

The original type of control using single anode rectifiers under the control of an electronic amplifier is being used, basically unchanged, but development is being carried out upon the static phase-shift network which is the link between amplifier and power rectifier. Modifications are being incorporated to simplify the present critical assembly requirements of this network, and to provide more margin to cover the effects of mains supply fluctuations.

The control equipments now being built for the Witton-James-Wood Autopaster incorporate built-in test circuits to simplify setting up and to facilitate running for routine checking.

## RECTIFIER MOTOR DRIVES.

A simple type of current limit control has been developed for use with large variable-speed D.C. motors, the speed of which is controlled by varying the voltage applied to the armature by a grid-controlled mercury-arc rectifier. In circumstances where the motor is driving a machine imposing a steady load, as in the case of a fan, if there are any disturbances in the A.C. supply due to direct-to-line starting of large motors, for example, it is possible that the D.C. motor may slow down appreciably during the A.C. voltage dip, so that a heavy current is taken as the motor is accelerated during the recovery of the voltage.

The current-limit control consists of a transductor which produces a signal proportional to the armature current of the D.C. motor. This signal is applied in opposition to a reference voltage in such a way that when it exceeds the reference, it has the effect of retarding the phase of the voltage applied to the grids of the mercury arc rectifier. This is achieved by a static phase-shift network connected in cascade with the mechanical phase-shifter used for normal speed control of the motor.

Where speed of response is not so important as it is in the above case, an alternative non-electronic type of current control may be used as in the case of the equipment supplied to Melbourne and Metropolitan Tramways Board. In this installation the output of the transductor is fed directly into the control coil of a regulator, which is mechanically coupled to a rotary phase-shifter.

## PHOTO-ELECTRIC EQUIPMENT.

Hitherto the application of photo-electric devices has been limited by the distance over which the ray of light could be effectively projected. This problem has been successfully solved in an equipment recently developed and distances of over 1,000 yards using white light, or half that distance with infra-red light, now present no difficulty.

With this apparatus (fig. 60) the boundary protection of factories, army camps and aerodromes can be accomplished in the most reliable way, and an order now in hand covers equipment for installing around the 12-mile perimeter of a secret site in the British Commonwealth. In this instance infra-red light is used because a white light would betray its presence at night.

The projector lamp house transmits a ray of light which is modulated by being interrupted at high speed. Such a light ray striking the photo-electric cell produces an intermittent current signal of a frequency corresponding to the rate of interruption. This signal is amplified in stages, the first amplifying valve being housed in the receiver unit. Amplification is completed and the signal rectified in a separate self-contained amplifier, designed to operate on a 230-volt, single-phase, 50 cycle supply. This unit also houses the high and low voltage sources of supply for the photo-electric cell and amplifying valves.

After rectification, the signal is passed to a sensitive relay which operates immediately the light ray is broken and initiates the operation of the various protective devices, such as visual and audible alarms, associated with the installation.

Telescopic sights and precise means of adjustment are provided for aligning the projector and receiver units so that the light ray falls accurately on the photo-cell.

Being unaffected by steady light, the equipment will operate effectively even in bright sunlight. Furthermore, it cannot be rendered inoperative by shining a torch on to the receiver unit. Another advantage of using a modulated light ray is that amplifying apparatus of conventional design can be used.

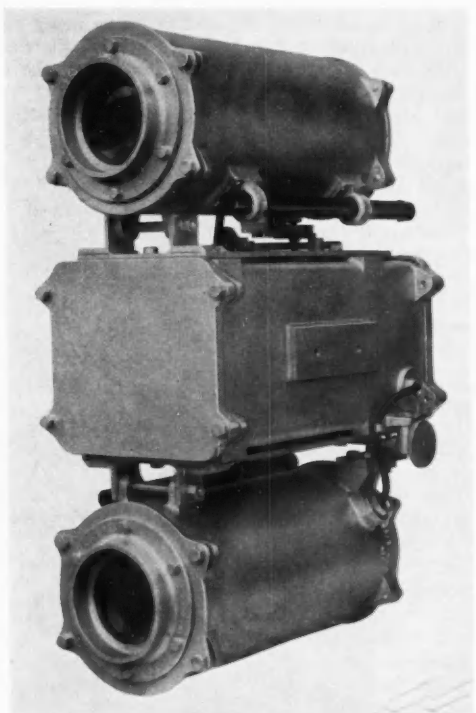


*Fig. 60.—Projector, amplifier and receiver unit for double ray operation.*

# Plastics

The past year has been one of steady technical advance and rising production to meet the increased demand from outside firms. Two extensions to the buildings have been brought into use during the past twelve months and have increased the facilities for injection moulding of thermoplastic materials and the assembly of Mutac switches and so forth.

*Fig. 61.—New injection moulding shop at Witton Moulded Insulation Works.*

In the new injection moulding shop (fig. 61) where mouldings are made of thermoplastic materials, there are now two 32 oz., seven 8 oz., and two 2 oz. moulding machines. The 32 oz. machines are capable of producing large mouldings such as refrigerator breaker strips and the fronts of television cabinets. The materials used are "Diakon", cellulose acetate, polythene, nylon and polystyrene. There are now various grades of toughened polystyrene available which give greater impact strength. The rearrangement of the machines in this shop has resulted in increased efficiency and enabled various devices, such as mould temperature control units and automatic weighing hoppers, to be put into use. This has helped in the solving of many technical difficulties which are met with in such mouldings as the egg rack, which is shown being withdrawn from the press in fig. 62.

In the sphere of thermo-setting mouldings, there has been no increase in the number of presses but the output from existing presses has been improved by the use of mechanised tools and the adoption of semi-automatic press control gear developed at Witton. An interesting development in the thermo-setting field is the 40-80 amp. plugs, sockets and junction boxes, constituting a complete power distribution kit for use by the Army in the field. Produced in a high impact grade of phenolic material, this kit has been designed to withstand rough usage and is resistant to moisture and exposure under all conditions of climate. Field trials have been extended and rearranged to permit a considerable increase in output.

In the extension to the Assembly Shop a new range of Mutac switches rated at 5 amp. and designed for use in plaster depth boxes is now in production. Microgap switches for handling currents up to 60 amp. are now firmly established and are extensively used in the DW range of ironclad switchgear. The 20-amp. double pole switch is in great demand, particularly for the control of water heaters.

Another assembly item is the right-angled torch made from tough cellulose acetate material which is now in full production. Different models are available for civilian and Service use. The torch is equipped with a strong clip which can be fastened to pocket or belt, thus leaving both hands free.

*Fig. 62.—Egg-rack moulding being withdrawn from an injection press.*

# Industrial and Process Heating Equipment

The increasing demand for metals for service at high temperatures has called for advances in brazing methods ; consequently a technique has been developed for the copper brazing of stainless steels, and for the brazing of these and other metals using certain proprietary high temperature brazing alloys. The operation takes place in a sealed metal container in which there is an atmosphere of very dry hydrogen. This prevents oxide films from being formed on the components to be brazed or on the brazing alloy. The container is heated in a vertical cylindrical furnace and any type of brazing which requires temperatures within the range 700 deg. C. to 1,180 deg. C. can be undertaken. Examples of brazed components are shown in fig. 63.

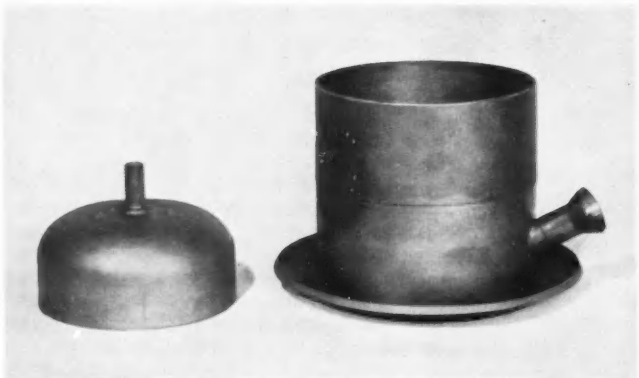


*Fig. 63.—Examples of joints made with high temperature brazing alloy. On the left, a mild steel stud has been brazed to a nickel alloy cup and, on the right, two cylinders of nickel alloy have been brazed and a spout joined to the lower one.*

An electronically controlled seam welder (fig. 64) has been developed for the joining of very thin metal sheets at a speed of 2 ft. per minute. It will handle steel sheets 10 mils thick, Inconel or nickel 6 mils thick and stainless steel, brass or copper 3 mils thick. The welds are of 1 cycle ($\frac{1}{50}$ second) duration and can be spaced with intervals of 2, 3 or 4 cycles between them, giving 42, 31 and 25 welds per inch respectively.

The welder has top and bottom electrode discs of chrome copper. The electrode surface on the lower disc comprises a continuously moving 18 S.W.G. soft copper wire, used directly from the reel on which it is supplied. It is taken over pulleys round a groove on the bottom disc and then to a driven take-up reel. By this means wear of the electrode wheel is avoided, there is no need for it to be re-dressed and no risk of its diameter decreasing and so affecting the match between the speeds of the electrode and the feed rollers. The rollers are arranged in two pairs before and after the electrode wheels, to keep the work flat and taut and the seam straight. The lower rollers, lower electrode wheel and wire take-up wheel have a common drive unit. Welding current and pressure are continuously variable, the latter between 20 and 100 lb.

A horizontal batch-type furnace has been introduced for case hardening steels by the carbo-nitriding process. In addition to the heating chamber, this furnace has a purging section, an oil quench tank and a cooling chamber. The whole process, including an oil quench or cooling in the carbo-nitriding atmosphere, can therefore be carried out without exposing the charge to air and without cooling the heating chamber. Fig. 65 shows the furnace, which is arranged for front operation and has hydraulically operated doors and quench gear. The cooling chamber and the quench tank are water-cooled and the latter is fitted with agitating propellers. The heating elements in the chamber are totally enclosed.

Small parts are carbo-nitrided in wire mesh baskets placed on a grid carrier tray, which is moved manually in or out of the furnace from a roller-top charging table. Alternative charge-carrying platforms allow cooling or quenching to be carried out while another charge is in the heating chamber. A furnace to handle small parts in batches weighing 250-300 lb. would have an overall length, including charging table, of 13 feet and a height of about 12 feet.

For general research and other work at high temperatures (up to 2,000 deg. C.) there has been a need for a simple, robust furnace, economical in its

*Fig. 64.—Electronically controlled seam welder for joining thin metal sheets.*

power requirements. Two models have been produced, one for single-phase and the other for three-phase operation and both have been described in detail elsewhere*. They are designed for vacuum operation and employ cylindrical graphite resistor heating elements which give hot zones 5-6 cm. in diameter and 8-10 cm. high (fig. 66). A temperature of 2,000 deg. C. can be maintained with a power input as low as 5·5 kW, and if the uncharged furnace is switched on at full power it reaches a steady temperature in 15 minutes.

Information about an important G.E.C. furnace installation (fig. 67) at the Springfields Atomic Factory has recently been released. The installation includes fifty-four 100 kW vertical cylindrical furnaces and two-hundred furnace pots, together with associated control equipment, unloading gear and cranes. The pots are about 3½ ft. in diameter and 7 ft. long, and the maximum furnace temperature is 750 deg. C. The equipment is used for the first of two stages in the conversion of pure ammonium diuranate to metallic uranium.

Vertical cylindrical furnaces are used for many other metallurgical processes. A 275 kW installation for the bright annealing of copper strip in coils is shown in fig. 68. The furnace takes charges weighing up to 3 tons in containers which are over 12 ft. in length. The handling gear to the right in the illustration is used for up-ending the coils of strip on to carrier plates to facilitate charging the containers.

* "A High-Temperature High-Vacuum Furnace for Experimental Work" H. D. BLAKELOCK and C. F. MACHIN, *The Engineer*, July 17th, 1953.
"High-Temperature High-Vacuum Furnace" H. W. DAVIDSON and T. H. BURWOOD, *Engineering*, Vol. 177, No. 4591, January 22nd, 1954.

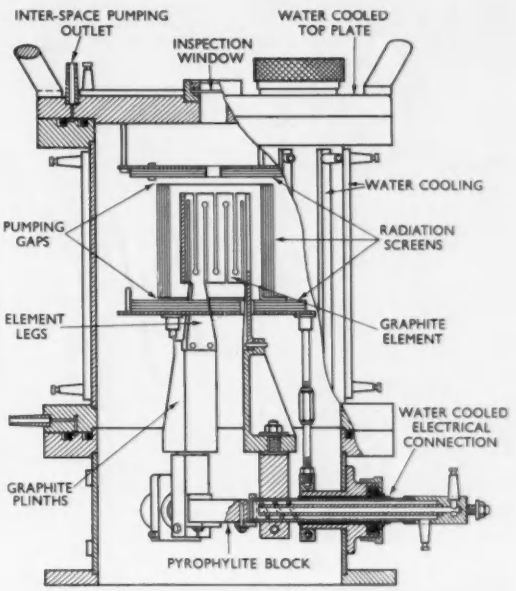



*Fig. 66.—Section through high temperature graphite-resistor furnace.*

A 56 kW nitriding furnace has recently been installed at the Coventry Works of Jaguar Cars, Ltd. for case hardening crankshafts. This vertical cylindrical furnace was supplied complete with fully automatic temperature control and recording gear, switchgear,

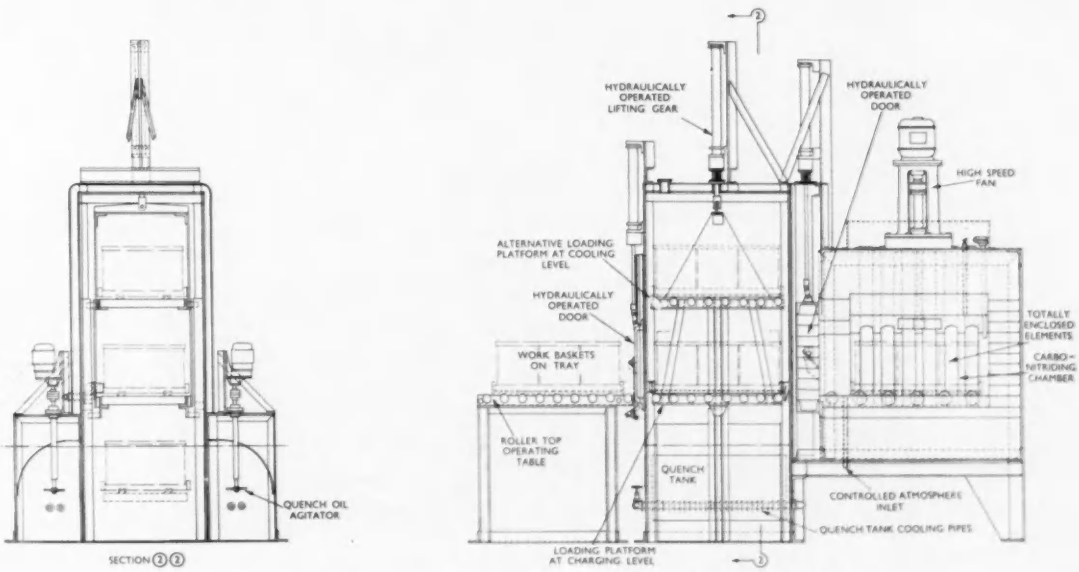



*Fig. 65.—Design drawing of horizontal batch-type furnace for carbo-nitriding.*

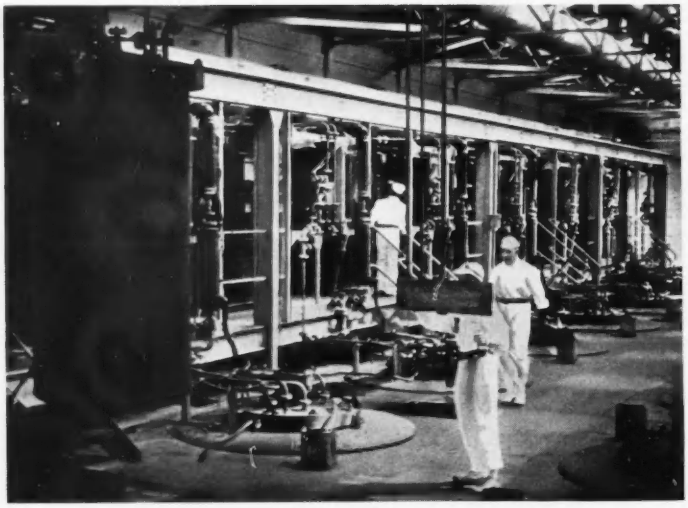


*Fig. 67.—Part of an installation of fifty-four 100 kW vertical cylindrical furnaces and 200 furnace pots at the Springfields Atomic Factory.*

ammonia flow panel, dissociation testing cubicle and two heat-resisting steel nitriding containers equipped with fans. A total heating cycle takes some 60-70 hours.

In another recent installation, for the scale-free annealing of steel wire, forced-air circulation is used at all stages : in the recuperator pit, inside the controlled-atmosphere-filled containers, and in the cooling pit.

Radiant heating has been applied successfully in many processes where lower temperatures are required. An important example is the setting of fabrics woven or knitted from nylon or terylene. This setting process involves heating the fabric rapidly to a temperature slightly below its melting point ; it imparts the qualities of dimensional stability and freedom from edge curling, and yields a material having good " handle " and " drape ". Rapid heating is particularly important as the fabrics become degraded and yellowed if held for any length of time at temperatures approaching their melting points.

Two types of heater used for this work are illustrated. One (fig. 69) incorporates sheathed wire elements in reflecting troughs, and in the other the radiating surface is a woven glass fibre sheet which is heated from behind by coiled nickel chromium elements. In use, the heaters are mounted over stenters which convey the fabric quickly past them. The normal exposure time for light fabrics is 8-10 seconds ; a 9 ft. long heater bank will handle material travelling at 20 yards per minute.

Modern practice in the design of radiant heating ovens for paint stoving is illustrated by the installation shown in fig. 70. The oven contains two vertical opposing banks of sheathed wire element reflector

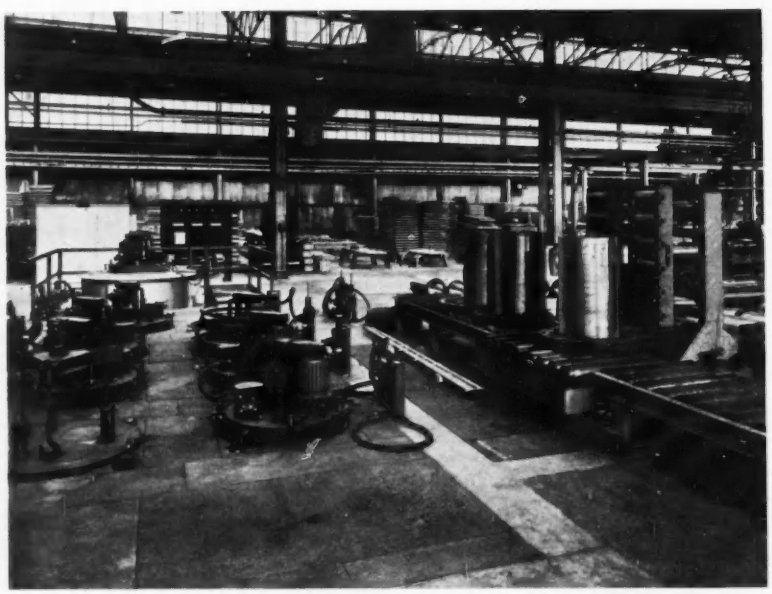


*Fig. 68.—275 kW furnace installation for bright annealing coils of copper strip. The furnace containers in the left foreground are in cooling and heat recuperating pits. The furnace proper is behind them.*

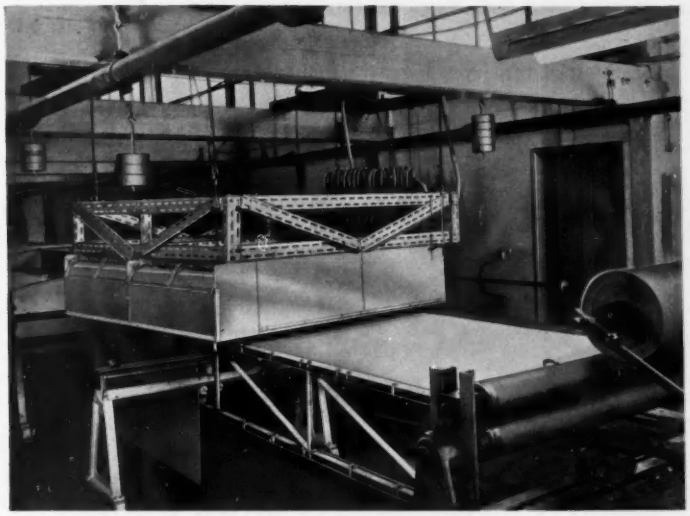


*Fig. 69.—Nylon setting oven, of the sheathed wire element type, mounted over a stenter.*

units. It is well encased and fitted with unheated entrance and exit vestibules to minimise heat losses, and as it is supported from the roof trusses and mounted well above head level it makes no demands on useful floor space. The oven has an overall length of 18 ft. and a maximum loading of 48 kW. The paint is stoved in about 2 minutes and some 400 parts can be dealt with per hour.

Reference was made in last year's Progress Article* to a small incinerator for destroying surgical dressings and sanitary wear. To meet the demands of establishments where it is not possible or economical to install a number of these small units, a larger model for central use has been developed. It is heated by tubular elements rated normally at 900 watts and has internal measurements of 12 in. by 12 in. by 18½ in. high.

The storage method of space heating, using energy supplied at a low tariff rate at night-time, has proved very popular especially for such places as offices, workrooms, schools and libraries. The original 1·5 kW heater, described in last year's Progress Article,† has now been supplemented by 1 kW and 2.25 kW models which will greatly extend the scope of the heating engineer in planning installations.

* *G.E.C. Journal*, Vol. XXI, No. 1, January, 1954, p. 42.
† *G.E.C. Journal*, Vol. XXI, No. 1, January, 1954, p. 44.

*Fig. 70.—Radiant heating oven for stoving paint mounted from the roof trusses.*

# Domestic Equipment and Household Appliances

New reflector fires, of the type specially designed to radiate heat evenly over a wide area in the horizontal plane, have been introduced. All these fires, one example of which is illustrated in fig. 72, comply with the safety requirements of British Standards Nos. 1670 and 1945.

A new basic range of immersion heaters is also in production. The automatic models, with thermostat pocket incorporated in the $2\frac{1}{4}$ in. B.S.P.T. head, are loaded at 3 kW and are available with immersed lengths ranging from 12 in. to 30 in. The non-automatic heaters, on $1\frac{1}{4}$ in. B.S.P.T. heads, are made in 2 kW and 3 kW loadings with immersed lengths of $10\frac{1}{2}$ in. and $14\frac{1}{2}$ in. respectively. Special attention has been paid to the question of making the heaters easy to wire.

Aluminium kettles are now available, the bodies of which are spun from a special type of sheet which has a surface cladding, on the side forming the interior, of very high purity aluminium. This method of construction gives improved durability without impairing the good mechanical strength characteristics of the base material. These kettles are more resistant to corrosion.

A new 8 cu. ft. domestic refrigerator (fig. 71) which is now being marketed conforms in outward appearance to the latest ideas in industrial styling. The door is made deep so that storage racks can be accommodated inside it, but is so shaped that the extra depth is quite unobtrusive. The door latch is of interesting design. Opening the door loads a catch by depression of a powerful spring, and when the door is shut, the latch is forced home by this spring and an air-tight seal is obtained without the necessity for slamming.

*Fig. 71.—The new 8 cubic foot domestic refrigerator.*

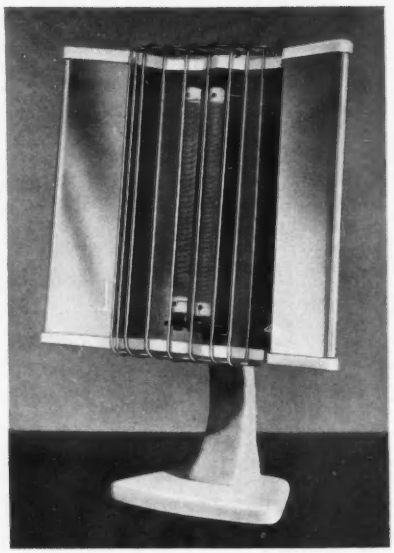


*Fig. 72.—" Cosyglo " reflector fire.*

The internal fittings, a special feature of which is a full-width freezer, have been designed with a view to ensuring a high standard of corrosion resistance. The freezer is made of stainless steel, plastics are used on the evaporator door and for all shelf supports and runners, and stainless materials for all small metal parts such as hinges and springs. The refrigerating unit is a development of the well-tried sealed system which has been in use for some years, and which has proved extremely reliable in service. Records over a period of seven years have shown that motor failures from all causes all over the world have amounted to less than 0·1 per cent. of the production.

Design and tooling have been completed for the production of a lightweight domestic floor polisher of a total weight of 14 lb. Light alloy pressure die-castings are used throughout and the universally wound motor, of unit construction, is resiliently mounted. An all-insulated handle grip and pole made in polyvinyl material operate an interlocking safety switch mounted on top of the motor. The revolving brushes, which are readily removable, are held in position on the square section of the drive pin by a snap action ball, and the driving disc tyres are of moulded rubber bonded in position. The appliance is doubly insulated, and interference with radio and television programmes is satisfactorily suppressed in accordance with the requirements of British Standard No. 800. Brushes and felt polishing pads are included in the equipment.

# Instruments

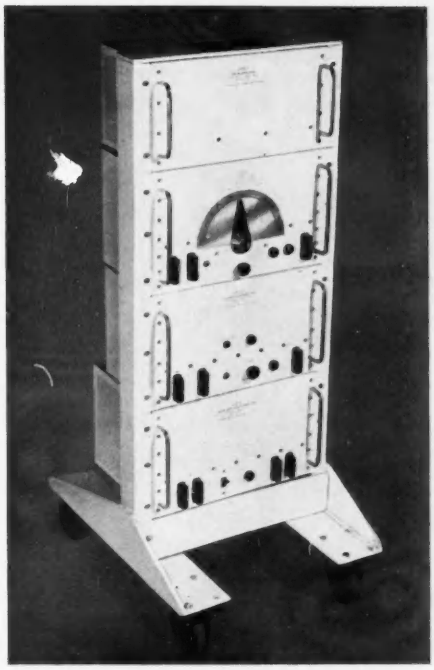


*Fig. 73.—Instrument designed for maintaining a stable low frequency supply.*

In some research projects and manufacturing processes, where the fluctuations in normal mains supply cannot be accepted, a source of power which is stable in output voltage and frequency is essential. An instrument has been produced which will maintain within ± 1 volt an output of up to 100 watts at any voltage between 200 and 250 volts and at any frequency from 34 to 66 c.p.s., despite mains variations from −10 to + 20 volts at the input. The instrument, which is shown in fig. 73, comprises four units : an oscillator of the Wien bridge type with amplitude stabilisation, a 100-watt amplifier, the amplifier power supply unit, and a voltage stabiliser. A simplified schematic circuit diagram is shown in fig. 74. The phase shift network and stabilising thermistor of the oscillator, and the thermistors used in the voltage stabiliser, are contained in a temperature controlled oven to overcome the effects of ambient temperature variations. When starting from cold, a warming-up period of 45 minutes is required and the highest stability of ±0·05 c.p.s. is not attained for 2½ hours, but this waiting period may be avoided by running the oscillator and stabiliser continuously.

Much apparatus used in the Forces is operated from batteries, and is often serviced by mobile repair stations which are also equipped to deal with mains-operated equipment. To save the trouble and inconvenience of maintaining and recharging batteries a unit known as a battery superseder has been designed. Basically it is a rectifier which takes in an A.C. supply of 230 volts 50 c.p.s. and gives out a supply of either 10-15 volts at 0-20 amp. or 20-30 volts at 0-10 amp. Overall efficiency is about 50 per cent. at full load, and power factor 70 to 80 per cent. A feature of the superseder design is the better regulation compared with that of a simple rectifier. An ordinary rectifier, together with the smoothing necessary to reduce the ripple to 1·5 per cent., would normally have a regulation from no-load to full load of about 20 per cent. ; by the use of saturable reactors with a feed-back circuit the figure has been reduced to about 4 per cent. in the superseder.

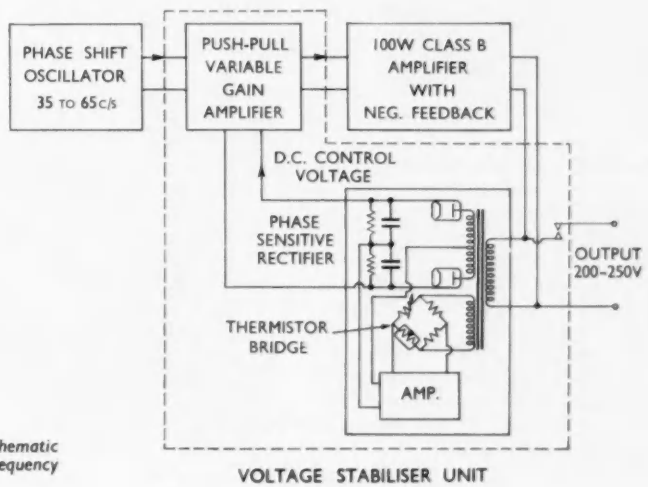



*Fig. 74.—Simplified schematic circuit diagram of the low frequency oscillator.*

Link testing instruments enable measurements of circuit conditions to be readily made without disturbing existing connections,* and two new types have recently been developed. One is the link testing power factor meter (fig. 75), which is a true single-phase power factor meter of the moving-iron type using a split-phase circuit. The accuracy is ± 0·05 in power factor over the ranges 50-250 amp. and 230-250 volts. Two scales are provided corresponding to current ranges of 50-100 and 100-250 amp. The links may also be used with interchangeable ammeter indicators to measure current up to 800 amp.

The other new link testing instrument is the miniature link testing ammeter shown in fig. 76, which is suitable for lower currents than the larger type previously available. The circuit comprises a split-core current transformer and a moving-coil rectifier instrument, and enables currents between 1 and 50 amp. to be measured on three switched ranges. With flexible conductors the lower limit may be extended by winding a number of turns of the conductor around one of the links. The accuracy is ± 5 per cent. of full-scale reading for frequencies between 40 and 80 c.p.s.

*Fig. 75.—Link testing power factor meter.*

The electromechanical transducer system, which was developed to provide remote electrical indication of small mechanical displacements, has been described previously.† It now appears that one of the major applications of this device (fig. 77) is the measurement of fluid pressures and flows. Government departments working on new projects have set exacting specifications for instruments that will measure these quantities. Hitherto, suitable instruments have been difficult to devise, but they become practical possibilities with the aid of the transducer system. Devices so far developed include flowmeters using differential pressure indicators, capable of withstanding high static pressures and high overloads in either direction, draught gauges and sensitive absolute pressure meters for use in the vacuum field. A special department has been set up for the design and manufacture of pressure responsive elements such as diaphragms, Bourdon tubes and metallic bellows. Most of the elements are made of beryllium copper, and most joints are silver-brazed using induction heating (fig. 78).

*Fig. 76.—Link testing ammeter.*

An interesting and valuable application of electrical measurement in the field of metallurgy is the carbon

*Fig. 77.—Pressure transducer.*

* *G.E.C. Journal*, Vol. XIX, No. 1, January, 1952, p. 62.
† *G.E.C. Journal*, Vol. XIX, No. 1, January, 1952, pp. 67-68, and Vol. XXI, No. 1, January, 1954, p. 47.

gauge, shown in fig. 79, which is used for measuring the quality of a carburising atmosphere. It consists essentially of a compartment with a transparent front, inside which an iron wire is heated electrically, and

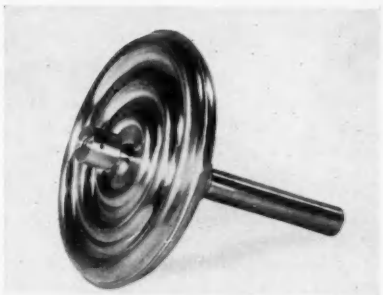


*Fig. 78.—A typical beryllium copper diaphragm "capsule," with electronically brazed joints, used for absolute pressure measurements.*

carburised in the atmosphere under test. The wire is then rapidly cooled so that it is transformed into martensite. In this condition the electrical resistance of the wire is a measure of its carbon content and hence of the carburising potential of the atmosphere. Values of the electrical resistance of the quenched wire can be directly related to carburising potential by the use of a calibration curve. Operation of the gauge is straightforward and one measurement takes about 15 minutes.

The carburising potential is that carbon content of a steel with which the atmosphere would be in equilibrium at a given temperature. For example, if the carburising potential of an atmosphere is measured on a gauge as 0·65 C, then this atmosphere would be neutral to a 0·65 C steel at the same temperature. This method of evaluating the quality of a controlled atmosphere is particularly useful in such processes as the neutral hardening of medium and high-carbon steel where decarburisation is to be avoided, the restoration of carbon to surfaces of parts which have been decarburised during casting or heat treatment, and the carburisation of steel to some specific value of carbon content.

The illustration shows a panel-mounted gauge, but where the instrument is required for use on several furnaces it can be supplied as a portable unit. The gauge wire runs through the compartment seen at the top of the panel. The carburising gas passes through this compartment and is burned as it emerges from the nozzle on the right. Heating current through the wire is adjusted by a variac. For measuring the resistance of the gauge wire after carburising, the voltage developed across it is measured for a small known value of current. The carburising potential can then be read off from the calibration chart.

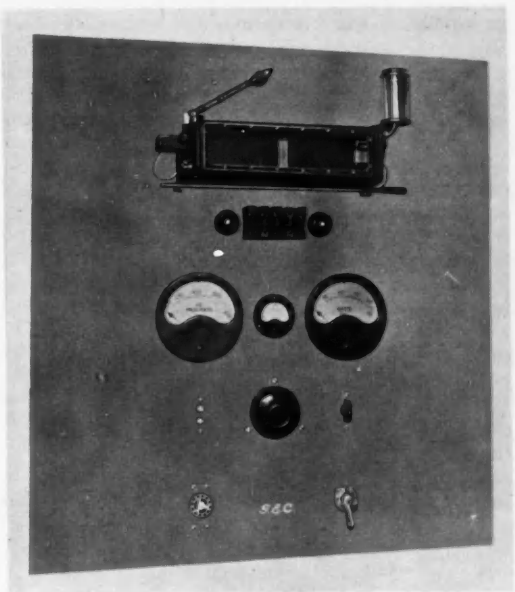


*Fig. 79.—Carbon gauge, for measuring the quality of a carburising atmosphere.*

# Lamps and Lighting

## LIGHT SOURCES.

### FLUORESCENT TUBES.

Osram fluorescent tubes in two new colours were marketed in March, 1954. Known as New Warm White and Deluxe Warm White respectively, they are the result of work on the development of new colours and will blend well with incandescent lighting. New Warm White is the most efficient colour in the fluorescent tube range, and has already achieved a wide popularity in commercial and industrial installations. The Deluxe Warm White tube is very similar in both colour appearance and colour-rendering properties to a gas-filled tungsten filament lamp, and is intended for installation where a warm colour with good colour-rendering characteristics is required. These new colours are available in both hot cathode and cold cathode tubes.

*Fig. 80.—400 watt MBF type lamp.*

Improvements of the order of 15 per cent. have been made in the efficiency of 5 ft. and 4 ft. Deluxe Warm White tubes. Similar improvements have been achieved in the range of Natural tubes which, in conjunction with the better colour-rendering characteristics reported last year,* have enhanced their value for general purpose lighting.

Starter replacement has been simplified by the introduction of a universal canister type starter switch, equally suitable for 3 ft., 4 ft. and 5 ft. tubes operated on alternating current.

### MERCURY AND SODIUM LAMPS.

Continuous improvements in techniques and control of manufacture have enabled a substantial increase—from 3,000 hours to 4,000—to be made in the declared life of sodium and high pressure mercury vapour lamps.

Market experience with 80 and 125 watt MBF lamps employing the phosphor with deep red fluorescence has confirmed the importance of this great improvement in the colour of HPMV lamps. A 400 watt MBF type (fig. 80) has now been developed which gives a similar colour improvement at even higher efficiency than the 125 watt lamp. Its good colour, small size and high luminous output are likely to make it important for street lighting in shopping centres and built-up areas. Work is proceeding on the development of a 1 kW MBF lamp. This will be of similar dimensions to the 1 kW MB lamp, which has proved invaluable for high bay lighting in industry, and will have the added advantage of the improved colour. A modified 1 kW MB lamp with a hard glass outer, for use under adverse atmospheric conditions, has been developed.

The increasing popularity of sodium lamps for street lighting has given added impetus to the work of improving their luminous efficiency and reliability. In this connection the work on sodium lamps has been directed towards a design embodying an integrated discharge tube and sealed jacket.

### TUNGSTEN FILAMENT LAMPS.

The demand for incandescent filament lamps appears to have been stimulated rather than reduced by the increasing use of fluorescent tubes. Since the incandescent lamp is still the most widely used light source, the effort to produce filament lamps of improved performance and uniformity continues year after year. Such improvements, not easily achieved for a product already developed to a high level of quality, require much patient study of results from extensive experiments and trials. The resulting gains in lamp quality may be small, but the cumulative effect of these small increases has, for example, enabled the efficiency of the lower wattage G.L.S. lamps to be increased by some 5-10 per cent. in the last twenty years. Such continued increases in performance and uniformity enable more stringent specifications to be drafted which are of direct benefit to the user.

A further stage in the simplification of bulb sizes for G.L.S. lamps has been reached now that the 75 and 100 watt single coil and coiled coil lamps are supplied in a 68 mm. dia. bulb, in Clear, Pearl, and Silverlight types.

A new series of Osram filament lamps operating at a controlled initial colour temperature of 3,250 deg. K. has been introduced. These lamps are intended for use with colour film balanced for 3,200 deg. K. and cover the range from 10 kW, in a bipost studio lamp, to the popular 275 watt and 500 watt photoflood types.

Lamps with medium bipost caps in ratings of 500 and 750 watts are now available, and for photographic enlargers the range of lamps from 40 to 100 watts may be

* *G.E.C. Journal*, Vol. XXI, No. 1, January, 1954, p. 55.

*Fig. 81.—Pendant fitting from the Gossamerlite range.*

provided with a special internal silica coating. For stage lighting, class T lamps in ratings of 250, 500 and 1,000 watts have been developed ; these employ mechanically locked capping to enable them to withstand the high operating temperature encountered in service.

PHOTOFLASH BULBS.

Two new flash bulbs with a blue lacquer coating have been introduced for use with colour film balanced for daylight. The coating raises the effective colour temperature of the emitted light from 3,800 deg. K. to 6,000 deg. K. and makes colour temperature correction filters unnecessary.

ELECTROLUMINESCENCE.

A small pilot plant is in operation to produce electroluminescent panels for certain highly specialised forms of lighting. A successful installation of these panels is now in use in the coating plant of a large manufacturer of photographic material.

## ILLUMINATION.

INTERIOR LIGHTING.

Fig. 81 shows a pendant fitting typical of the new Gossamerlite range for interior lighting. Thin, white or coloured wire, welded into attractive patterns, is used to give a light and inexpensive method of construction.

Experiments have been carried out with combinations of tungsten lamps and the new Osram 125 watt MBF lamp in blended light installations. An efficient combination giving excellent colour appearance is possible, and may sometimes be preferred to fluorescent tubes for industrial and even commercial use.

Many of the lighting fittings in the Royal Yacht Britannia are of a special design produced by the G.E.C. in collaboration with Sir Hugh Casson, consultant to the Admiralty for the interior decoration of the vessel. The decorative fittings include a dining-room ceiling unit in which a " coronet " effect is provided by cut glass prisms encircling the lamp. A

*Fig. 82.—Lighting of a large garage with Osram cold cathode fluorescent tubes. New Warm White is used in the showrooms and Intermediate in the forecourt.*

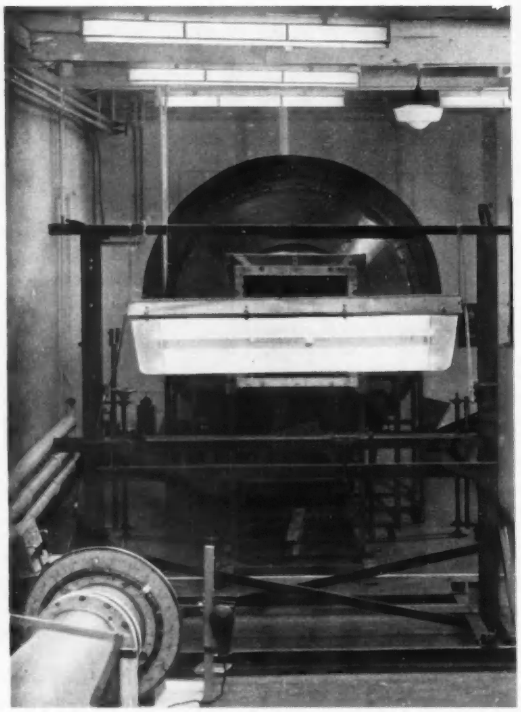


*Fig. 83.—Three-Eighty lantern set up in front of wind tunnel to study variation of light output with ambient temperature.*

faceted glass ball is mounted at the centre of a circular gold bronze plate which forms the underside of the fitting. Fluorescent cornice lighting has also been used. The tubes are mounted in a channel with the tube ends overlapping to avoid any breaks in continuity.

Fig. 82 illustrates the lighting of a large garage with cold cathode fluorescent tubes.

### Exterior Lighting.

The variation of light output from the Three-Eighty lantern with ambient temperature has been studied in an interesting series of experiments. The lantern is set up in front of a wind tunnel, so that the light output is measured in conditions as similar as possible to those encountered in service (fig. 83). The results of this research are summarised in fig. 84, which shows that the light output remains constant down to —20 deg. F. in still air, but the effect of a 10 m.p.h. wind is considerable ; under these conditions, the light output is constant down to 5 deg. F.

Two concrete columns for street lighting have recently been put on the market. Known as the " Altus " (for main roads) and the " Brevis " (for side roads), the columns combine pre-stressed high tensile and unstressed mild steel so as to provide high impact resistance and safeguard against cracking and subsequent steel corrosion. Both columns have been designed in accordance with the appropriate British Standard. The mild steel reinforcement also enables the " Altus " (fig. 85) to pass the impact test as agreed by the Ministry of Transport. The whole range has been approved by the Council of Industrial Design.

The first installation using cold cathode tubes for conventional street lighting was switched on in Aberdeen during the year. This was also the first major installation ever to use vertical fluorescent tubes exclusively, and provided the first instance of a main street of any great city being lighted by lanterns fixed on the walls (fig. 86). The lanterns are mounted opposite each other and about 70 ft. apart. Economy in power consumption and maintenance, together with the fact that no columns are required, are important advantages.

Modifications to the standard cold cathode lantern have improved its appearance and simplified access to the gear compartment.

A new aero-screened lantern, housing a 250 watt or 400 watt Osram mercury lamp, has been designed for use on roads near aerodromes (fig. 87). It has a die-cast silicon aluminium alloy body which carries special mirror reflectors, and open or enclosed versions are available. A special levelling adaptor is incorporated in the top entry mounting. Peak intensity occurs at 75° to the downward vertical, and the lantern, which meets the Ministry of Transport Specification, can be used at spacings normally employed for medium angle beam distributions. A normal main road cut-off lantern of similar construction has also been designed.

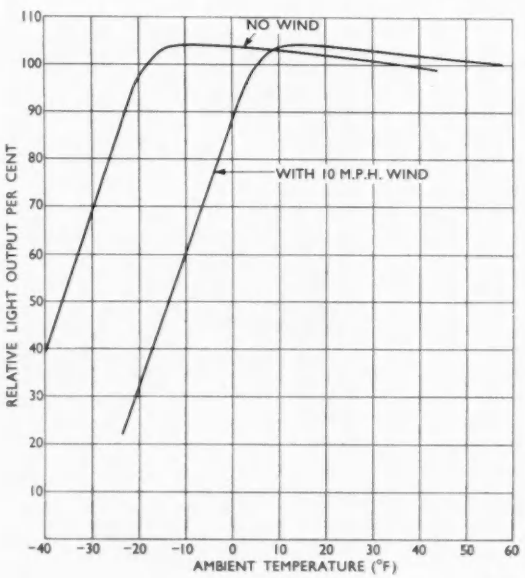



*Fig. 84.—Graph showing the variation in light output of a Three-Eighty lantern with ambient temperature.*

*Fig. 85.—" Altus " column for main roads.*

A new lantern for sodium lighting in main roads is constructed almost exclusively of plastics, giving exceptionally low weight (fig. 88). Consisting of a one-piece, open, inverted " Perspex " bowl, with

*Fig. 87.—Aero-screened lantern for use on roads near aerodromes.*

" Perspex " refractor plates bonded to the inside, the lantern houses a sodium lamp of 85 or 140 watts.

Two new open type lanterns for side roads are now available, for use with low wattage tungsten filament lamps or an 80 watt mercury MB/U lamp. These lanterns have cast iron bodies. One has a white vitreous enamelled conical reflector only, and the other an open " Wembley " optical system using a prismatic glass dome refractor.

A range of small, cut-off lanterns has been introduced (fig. 89). These are also for side road lighting, particularly near aerodromes and for dock and waterside service, and use low wattage tungsten lamps or 80 or 125 watt MB/U mercury lamps. Open or enclosed versions are available, both having a cast iron top and a spun copper main body which carries a silvered reflector. By the use of differently shaped

*Fig. 86.—Street lighting in Aberdeen, with cold cathode lanterns fixed on the walls.*

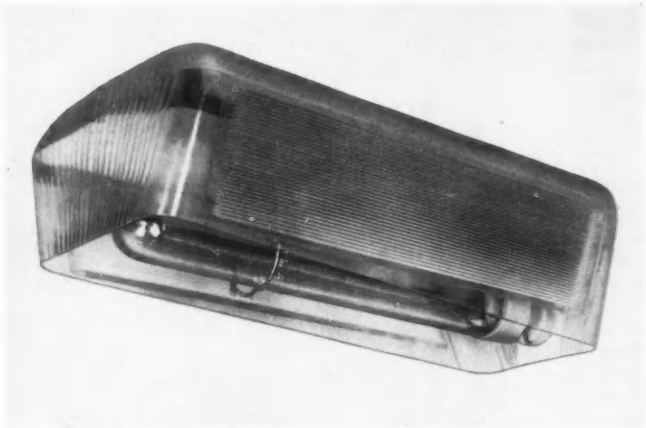


*Fig. 88.—" Perspex " lantern for sodium lighting on main roads.*

reflectors and by making certain focusing adjustments, the light distribution can be symmetric, asymmetric or non-axial asymmetric.

Another new lantern, designed primarily for quayside and dock lighting where a high level of illumination is required, is equipped with two 400 watt mercury MA/H lamps. This lantern (fig. 90) has an anodised aluminium reflector rigidly fixed between two silicon aluminium end castings. Each end casting has a hinged door, with waterproof gasket, providing access for relamping. The front is of toughened roughcast diffusing glass sealed in a substantial cast aluminium frame, making the lantern virtually hermetically sealed and completely dust and weatherproof. It is arranged to clamp on to a vertical pole, and the beam axis may be varied between 20° and 50° below the horizontal by altering the angle of elevation of the projected light.

Two new prismatic bowl refractors have been produced for use with side road lanterns. One is a prismatic glass shallow bowl with improved optical characteristics and appearance. The other is unique in that it is the first injection moulded " Perspex " prismatic bowl produced in the United Kingdom. Great accuracy of optical control is possible with this method of production.

Tests have been made with an improved design of floodlight for football grounds, and a unit for lighting smaller sports grounds has been developed.

### Aerodrome Lighting.

A new aerodrome traffic control light (fig. 91) has been introduced as a replacement for the older type, which has been found to be too heavy for operators to hold conveniently for long periods. The new unit consists primarily of a lightweight sheet aluminium housing containing a 6 volt, 50 watt projector lamp and anodised aluminium parabolic reflector. Total weight, excluding the flexible lead, is 3½ lb. The light may be changed to green, red or white at will, and is flashed by means of a trigger-operated shutter. A second trigger incorporates a switch to ensure that the light is not left burning when not in use. An intensity of about 130,000 candelas (white) is obtained, which is adequate for signalling to aircraft in bright sunlight.

New versions of the high and low intensity elevated runway and taxiway lights have been produced, following the general tendency towards the elevated

*Fig. 89.—Cut-off lantern for side road lighting.*

*Fig. 90.—Quayside lantern, shown mounted on a pole.*

type of equipment. The runway light originally equipped with glass upper reflectors and a " Perspex " cover dome is now suitable for a 200 watt lamp, which necessitates the use of metal reflectors and a heat-resisting glass dome.

For runway lighting installations where elevated lights may not be used, the flush threshold light shown in fig. 92 has been introduced. It uses a 100 watt lamp, and light distribution is in the form of two medium intensity green beams projected parallel to the axis of the runway. The unit is designed to withstand the shock of being run over by aircraft.

Development work for the Ministry of Supply is proceeding in connection with aerodrome identification beacons and aircraft carrier deck landing lights used in conjunction with the " mirror sight " landing aid.

### Sign Lighting.

An outstanding illuminated advertisement in Piccadilly Circus, London, was recently completed by Claude-General Neon Lights Ltd., for " Coca-Cola ". The sign covers approximately 2,000 sq. ft. and almost a mile of neon and " Cleora " fluorescent tubing is used in it. The design consists of a tube background of 35 concentric circles in Ruby Red, on which the advertising legend is superimposed (fig. 94). The letters in the word " Coca-Cola " measure 10 ft. and 5 ft. upper and lower case respectively and have an opal plastic face to give a pleasing daylight appearance.

A flasher is used to bring the various parts of the sign on in suitable sequence, and there are 99 transformers with a total load of 26 kW operating the installation. A time switch and a photo-cell circuit are incorporated to switch the sign on in dull weather and at dusk.

During the year, additions have been made to the " Cleora " range of fluorescent colours for sign work.

*Fig. 91.—The new aerodrome traffic control light.*

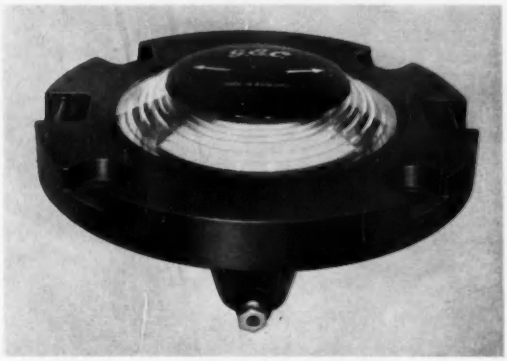


*Fig. 92.—Runway threshold light for flush mounting.*

The new colours are : Jasmine Yellow, the most efficient yellow yet produced ; Ice Blue, a halophosphate powder of good efficiency ; and Magenta, a new powder in which the fluorescence is excited by neon discharge.

It has been found that in cold weather the mercury in a cold-cathode tube tends to migrate to the centre of the tube, so that the discharge near the electrodes takes place only in the argon gas filling. Very little ultra-violet radiation is thus emitted from these portions of the tube with a consequent decrease in the light output. This effect has been overcome by the use of a new design of electrode. A trap situated at the outer end of the electrode, and formed by a mica baffle which fits closely to the glass walls of the electrode case, is used to hold the mercury dose. No liquid mercury can then escape into the tube, but eyelets in the baffle permit the egress of mercury vapour. A further advantage of the new electrode is that it prevents the movement of a globule of mercury during transportation and any consequent stripping of the powder from the tube walls.

### Studio Lighting.

A 10 kW Studio Spotlight designed specifically for films and television work has been added to the range. Adequate ventilation is provided to ensure that the maximum lamp life is obtained and to eliminate bulb distortion. The optical system takes a 20-in. fresnel lens of either flat or dished contour.

A new porcelain lamp holder for bipost projector lamps is being introduced. This incorporates several novel features to enable it to stand up to heavy loads,

*Fig. 93.—Studio " Six-Forty " fluorescent floodlight.*

and assumes particular importance now that a 10 kW lamp is available.

Fig. 93 shows the studio " Six-Forty " fluorescent floodlight, which may be used either as a " broadside " or an " overhead ". Two-ft. 40 watt tubes are used. The unit is fitted with a swan-neck bracket terminating in a tubular stem with a $1\frac{1}{8}$ in. dia. spigot, so that it can be mounted on any existing standard studio lighting stand. Independent switching of each pair of lamps is provided, and a two-door Barndoor is available as an optional extra.

### Mine Lighting.

The work of developing special fittings for lighting mine roadways is nearing completion. The project began some four years ago when actual working conditions in collieries were studied, after which a model, simulating the appearance of 120 ft. of typical full-size mine roadway, was constructed at the Research Laboratories. Using the model for studies of the lighting problems involved, special fittings were evolved which were later tested in actual installations. The tests gave excellent results, confirming the validity of the model experiments.

The flameproof version of the fitting mentioned in last year's Progress Article* has been produced, and after checking in the model mine some have been installed in a colliery for full-scale tests. The model and the actual mine were both lighted by the new equipment, which consists of 60 watt well glass flameproof fittings with special refractors. The light distri-

* *G.E.C. Journal*, Vol. XXI, No. 1, January, 1954, p. 62.

*Fig. 94.—The " Coca-Cola " sign in Piccadilly Circus, London.*

bution provides for minimum intensity along the centre line of the roadway, rising to a maximum a few degrees each side. This gives more even lighting of the walls when maximum spacing is used, while reducing glare to the minimum on the roadway itself.

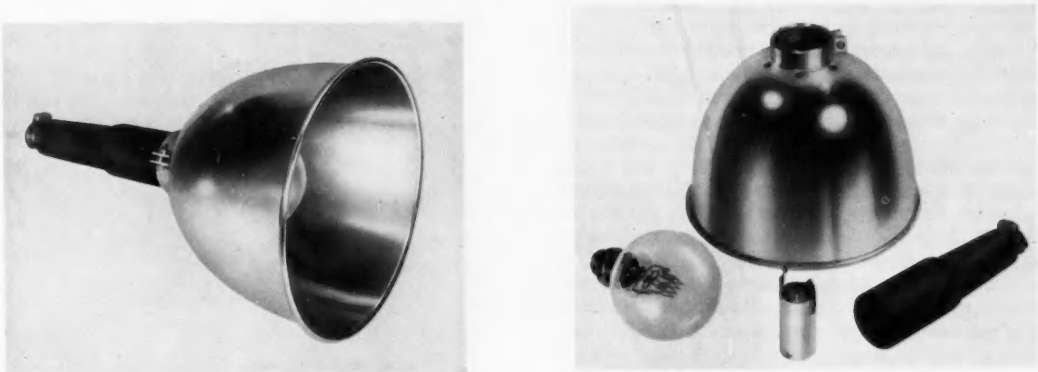


*Fig. 95.—1,000 watt lamp and fitting for underwater use.*

FLOODLIGHT FOR UNDERWATER TELEVISION.

An underwater floodlight with a 1,000 watt Osram lamp* was used in conjunction with television apparatus during the search for wreckage of the Comet aircraft which crashed off the Isle of Elba in January last year. The lamp and fitting (fig. 95) were developed by the Company in collaboration with the Admiralty Research Laboratories.

A light which would not require a heavy or complicated fitting had to be produced, hence it was necessary to design a bulb which could be exposed to water when the lamp was alight, the fitting being merely a simple reflector giving mechanical protection. After a series of experiments a 100 mm. diameter round bulb, with 1 mm. wall thickness, was adopted, able to withstand a pressure of 650 lb./sq. in. This represents a depth of about 1,500 ft. A special rubber moulding was produced to protect the lamp cap from water. For the purpose intended, a premium was placed on high efficiency and a figure of 24·5 lumens per watt with a mean objective life of 50 hours was achieved. The lamp must not be operated out of the water.

A simple, anodised aluminium reflector shrouds the lamp to protect it from mechanical damage, and the lamp, reflector and accessories together weigh only about 3 lb. When used for underwater television the fitting is attached to the camera by an arm, so that the area illuminated always corresponds to the lens viewing angle.

* *G.E.C. Journal*, Vol. XXI, No. 1, January, 1954, p. 56.

# Telecommunications

## TELEPHONES.

The 12-circuit and 3-circuit open-wire line telephone transmission equipments have been redesigned to conform to British Post Office " type 51 " practice. All panels, each containing a separate stage of the transmit or receive circuit, can be removed from the rack side without disconnecting any wiring. The 3-circuit system in particular (fig. 96) is notable for its wide bandwidth, overall frequency stability and sensitivity, and for the inclusion of telegraph facilities.

Development work on circuit design for automatic telephony has aimed at providing added facilities for subscribers while achieving economies in administration. A system has been devised for nation-wide subscriber dialling, using a technique by which calls can be routed from one exchange to another or through the distant exchange to a subscriber.

A new party-line system for eight subscribers per line has eliminated the need for dialling prefix or suffix digits. Each subscriber has a separate directory number, and selective ringing sounds his bell alone. No subscriber is obliged to replace his handset after dialling one of the others on the same line.

Among other new items of apparatus recently announced is a mobile rack containing a camera for photographing subscribers' meters. The pictures taken enable accountancy to be greatly speeded.

Polystyrene capacitors are now being mass produced, and a typical selection is shown in fig. 97. They are inexpensive, suitable for tropical service, and have a stability at least equal to that of silver-mica capacitors.

## RADIO COMMUNICATIONS.

An example of the harnessing of radio to the working of automatic telephony is provided by an inter-exchange radio link which replaces the normal physical junctions. It offers a number of speech and signalling channels which can be governed by the automatic equipment at each end of the link. In addition, a shared party subscribers' radio link, on two-frequency working, provides both revertive and trunk calls through the exchange to which the link is connected.

New equipment, conforming to British Post Office " type 51 " practice, has been produced to transmit microwave television signals. The system, which operates in the 2,000 Mc/s band and transmits up to a 625-line picture, was used in the Eurovision links across the Swiss Alps and the English Channel.

## FOUR-CHANNEL PROGRAMME TERMINAL EQUIPMENT.

Apparatus has been developed for multiplexing three programme transmissions and an engineer's transmission, using time-division multiplex and pulse time modulation. The multiplexed signal may be transmitted over a radio link of the type normally used for the transmission of television signals. (Such a link would not normally be suitable for the transmission of a frequency division multiplex signal.) The three programme circuits meet the C.C.I.F. recommendations for normal programme circuits, and the specification is briefly as follows :

(*i*) Crosstalk better than —74 db.
(*ii*) Flat noise better than —37 db.
(*iii*) Weighted noise better than —57 db.
(*iv*) Frequency response ± 1·5 db. from 50 c/s to 10 kc/s (10 kc/s channel bandwidth).
(*v*) Individual distortion components less than 1 per cent., at the maximum useful level of the channel.

The equipment is made up of two 4 ft. 9 in. bays (transmitter and receiver) of " type 51 " construction, each bay having a power consumption of approximately 250 watts. The three programme circuits and

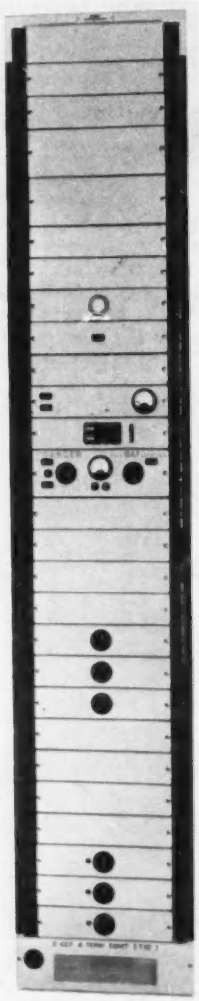
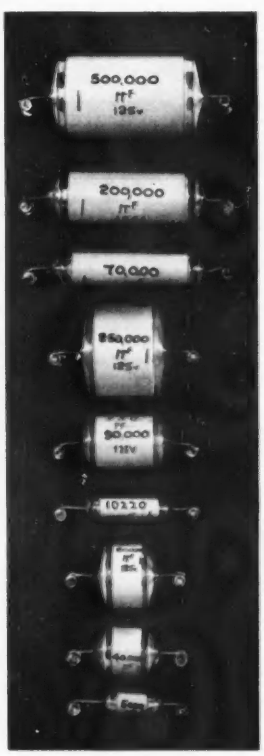


*Fig. 96 (left).—3-circuit open-wire system terminal rack.*

*Fig. 97 (below).—A selection of typical polystyrene capacitors.*



the engineer's circuit enter the transmit terminal in 600 ohms balanced impedances, and the maximum useful level of each channel is + 8 dbm. The multiplexed signal leaves the bay as a positive-going pulse train of 1 volt amplitude in an unbalanced impedance of 75 ohms. At the receive terminal these figures apply in reverse.

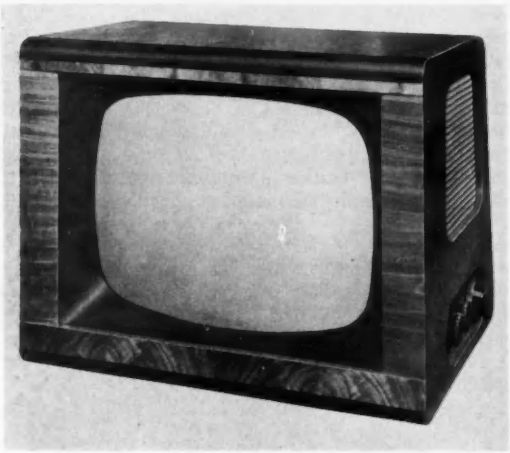


*Fig. 98.—Table model television receiver with 17 in. screen.*

CATHODE RAY TUBES.

In order to effect economies in the production of the popular 14 in. television tubes, a non-aluminised type with ion trap has been developed, and is now in production in addition to the aluminised version. Slight modifications have been made to the gun of all 14 in. tubes to minimise deflection defocusing.

A 17 in. aluminised rectangular television tube is in factory production. It incorporates a triode gun designed to give a small spot and negligible deflection defocusing with a scanning angle of 70°. Larger tubes up to 21 in. diagonal, and tubes with a 90° scanning angle, have been developed.

Studies of the fundamental properties of electron guns have led to the development of new electrostatically focused tubes in which beam trimming has been reduced to the minimum. Although more expensive to produce, these tubes may lead to overall economies in the cost of television receivers owing to the elimination of focusing magnets.

TELEVISION RECEIVERS.

The coming of alternative programmes has brought about major changes in receiver design and technique.

Provision is made in all standard receivers for reception on Band I and Band III, with programme selection by means of a three-position switch. This is arranged for one station in the existing Band I, used by the BBC, and two stations in Band III, which will be used for the alternative programmes. Each switch position can be tuned over the whole range of its respective band, but as only two channels are available at present in Band III, receivers are pre-tuned to these channels at the factory; the sets are therefore ready for switching to the alternative programmes as soon as they begin.

Of the many circuit improvements which have been made, the most important is the introduction of mean level automatic vision gain control. This holds the picture substantially constant over the large variations of signal input which may occur when switching from one station to another. Also the effects of fading and of aircraft flutter are virtually eliminated.

The 14 in. rectangular tube table receiver has been retained, and the demand for a larger picture has been met by the introduction of a 17 in. table receiver of similarly compact design (fig. 98). Three console models are available, all using the same basic chassis; one has the 14 in. rectangular tube, the other two the 16 in. dia. round tube (fig. 99).

There are, in addition to the foregoing, fringe models having circuitry specially developed to give extra high sensitivity. "Fly-wheel" synchronising of the time bases has been introduced to ensure steady pictures despite heavy interference, and improved automatic vision gain control is also incorporated to counteract the deep fading often experienced outside the recognised television service areas. These fringe models—there are two table receivers using 14 in. and 17 in. rectangular tubes—are tunable over the five existing BBC Band I channels only, as Band III

*Fig. 99.—Contemporary style console television receiver using 16 in. round tube.*

reception is expected to be difficult in fringe areas. The sets are, however, designed to have an all-programme adaptor fitted quickly and easily when alternative programmes begin.

A team of G.E.C. engineers took a mobile laboratory on to the European continent to study reception

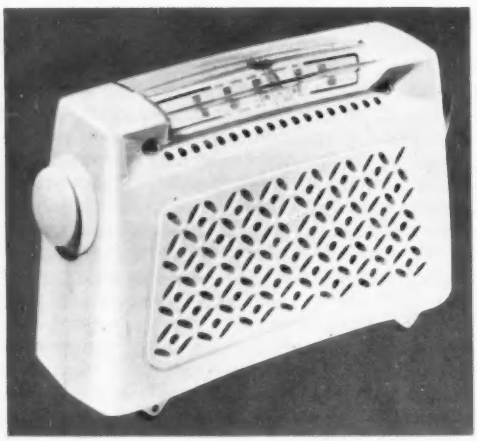


*Fig. 100.—Mains portable radio receiver with polystyrene moulded cabinet.*

problems. The knowledge they gained subsequently proved valuable in the design of an export television receiver suitable for mass production.

A television transmitter has been built at the Research Laboratories at Wembley to broadcast pictures on export standards, using frequencies in Band III. Several months of operation have yielded valuable experience for the design of receivers for both home and export markets.

**RADIO BROADCAST RECEIVERS.**

A new lightweight mains portable receiver recently introduced for the home market has a cabinet moulded in polystyrene in a choice of colours (fig. 100). The cabinet is of transparent material, which enables a novel effect to be achieved by applying the colouring to the inside. The receiver has a 4-valve plus metal rectifier circuit covering long and medium wavebands, and a ferrite-rod type of aerial.

The styling of the new high-grade table radiogram shown in fig. 101 makes it particularly suitable for a small room. A 5-valve 3-waveband receiver with built-in tuned frame aerial is incorporated, together with a 3-speed automatic record changer.

For export, the comprehensive range of receivers previously described continues to be available, with the addition of a new 6-valve model (fig. 102). This has an attractive wooden cabinet and employs the band-spread detent tuning technique. A tuning indicator is fitted.

**SOUND EQUIPMENT.**

A 15-watt industrial radio receiver for long and medium wavebands has been added to the range of sound equipment (fig. 103). Gramophone and microphone amplifier channels are provided. It is available either rack mounted or in a metal cabinet, and will provide good quality radio reproduction in such places as hospitals, small industrial premises and schools.

The latest type low noise valves are fitted to a new 60-watt amplifier, which has connections for the take-off of power for the operation of a remote control or radio unit. For the comparatively low-priced market an 8/10-watt amplifier is now available. This model is made in chassis form only, enclosed in a metal cover finished in grey enamel. Microphone, radio and gramophone inputs can be accommodated, the microphone channel having sufficient amplification to allow a high-quality ribbon microphone to be used.

*Fig. 101.—High-grade table radiogram.*

To meet demands from railway and airport authorities, advertising agents and others, an automatic voice or music repeating machine has been designed which allows 25 pre-recorded announcements to be stored. Any one of these can be selected remotely and, by switching, can be broadcast over any loudspeaker system. The instrument is fully automatic and uses magnetic tape as the storage medium. Fig. 104 shows the control panel of a train-controlled announcement system at Stratford Station, Eastern Region, British Railways.

A boom microphone stand for general use has been put on the market. It can be adjusted vertically and horizontally, allowing full use to be made of a suspended microphone.

The G.E.C. metal cone loudspeaker (fig. 105), mentioned in last year's Progress Article*, is now in production. It represents an outstanding advance in

* *G.E.C. Journal*, Vol. XXI, No. 1, January, 1954, p. 54.

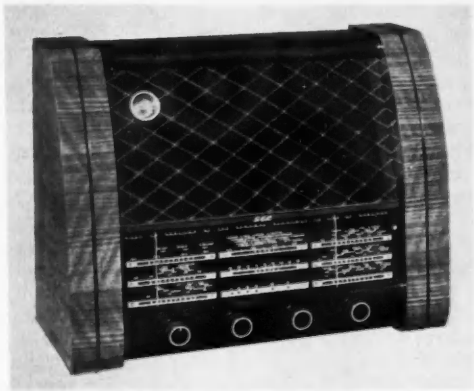


*Fig. 102.—One of the range of radio receivers designed for export.*

the technique of sound reproduction, having a sensibly flat frequency response over nine octaves. In addition to the use of a rigid metal cone, the design incorporates several new features which contribute to the loudspeaker's smooth frequency response.

To make the most of its high qualities, the metal cone loudspeaker must be mounted in a correctly designed acoustical chamber. The desired properties are to be found in the recently developed loaded-port octagonal cabinet (fig. 106) which, by means of a new principle, gives a smooth, efficient frequency response down to the lowest organ note despite the cabinet's relatively small size.

**VALVES.**

Three new experimental magnetrons with somewhat unconventional design features have been produced. The first, E.1936, is a low-power tunable valve operating in the 3,000 Mc/s frequency band. It employs the interdigital type of anode system, allowing an external resonant circuit to be used.

*Fig. 103.—15 watt industrial radio receiver.*

With the smallest circuit, the valve operates over the range 2,580 to 3,410 Mc/s; tuning is by single knob adjustment of the circuit, and the power output is within 4 to 8 watts. Other frequency ranges may be obtained by a change of circuit.

The E.2524 magnetron is a low-power, tunable valve for working in the 10,000 Mc/s frequency range.

*(Photograph by courtesy of British Railways)*

*Fig. 104.—Control panel of a train announcement system at Stratford Station, Eastern Region, British Railways.*

*Fig. 105.—Metal cone loudspeaker.*

It is a simple form of valve with a small glass envelope through which power couples directly to the load circuit. The principle of space component operation is used. This allows oscillation with useful power output with only two internal resonant circuits. Consequently there are no difficulties due to oscillation in alternative circuit modes, and very rapid start up of oscillations can be achieved. Power output is of the order of half a watt, and adjustment of the external circuit gives a tuning range of 5 per cent. Operating voltage is about 900 volts, with an efficiency of some 15 per cent.

The third magnetron, E.2124, has been produced for use in an experimental beacon operating in the marine radar band (around 9375 Mc/s). This valve uses the minimum voltage principle,* enabling a large anode to be incorporated together with a tungsten spiral cathode for long life. Tuning, which is required at a rate of twice per minute throughout life, is by a tuning rod inserted into one of the circuit cavities; the drive to this through the vacuum envelope is by means of a simple magnetic motor. A power output of the order of 5 watts is obtained at an anode voltage of 5 kV. To cater for unattended operation in a sea atmosphere, the valve is mounted in an oil-filled can on which the tuning motor is fixed. Forced-air circulation is unnecessary.

A tube employing a corona type gas discharge between coaxial cylindrical electrodes has been developed for use as a voltage stabiliser. By varying the pressure of the hydrogen gas filling, a tube of the same size as a miniature radio valve can be made to operate at a particular stable voltage between

* *Proc. Phys. Soc.* B. LXIII, p. 51 (1950).

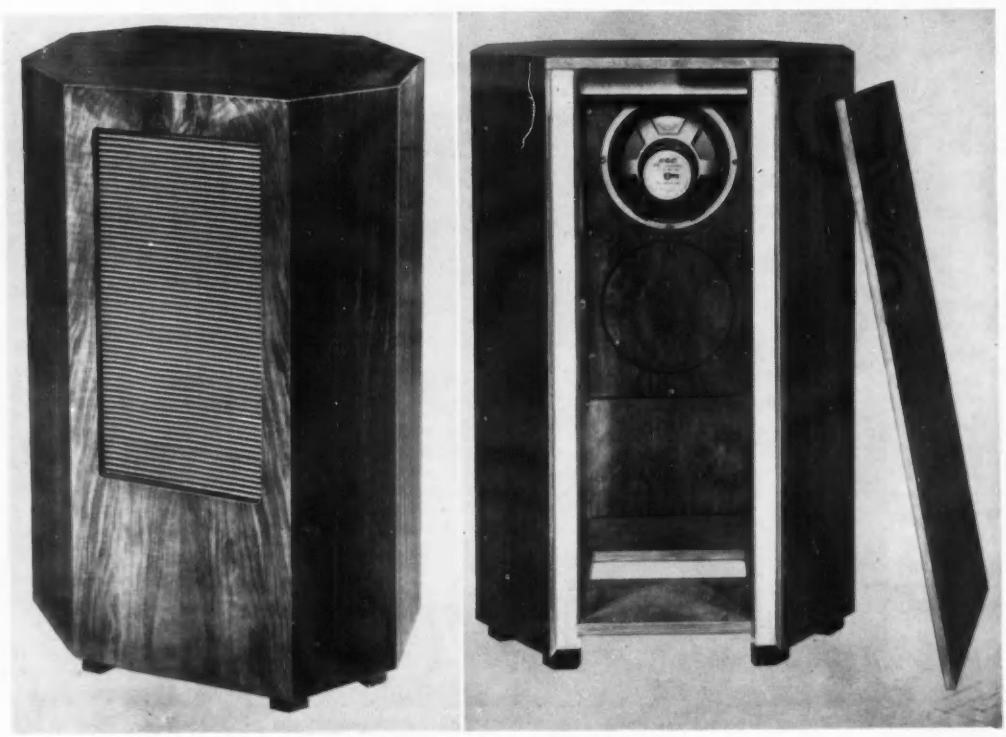


*Fig. 106.—Loaded-port octagonal cabinet.*

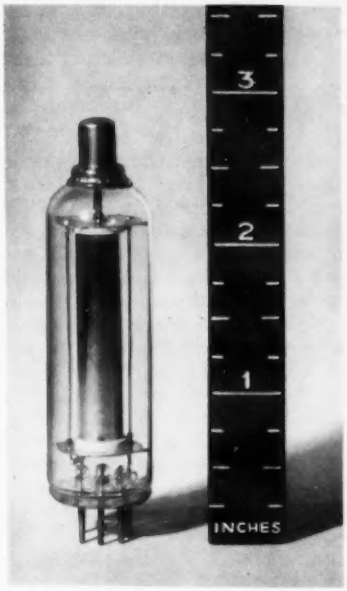



*Fig. 107.—Corona type gas discharge tube.*

300 and 1,500 volts and with a current up to ¼ mA. The variation of output voltage can be kept within about 1 per cent. of that of the input by operating the tube with a suitable series resistance. The device (fig. 107) is particularly applicable to H.T. supplies for Geiger or scintillation counters and small cathode ray tubes.

A new cold cathode valve has been developed for electronic switching, taking over many of the functions normally performed by electromagnetic relays. Known as the CCT6, it embodies several features not hitherto available in this type of device. These include the ability to operate at 1 to 5 mA continuous rating, or pulsed currents up to 40 mA ; a high signal output made possible by operation at H.T. line voltages up to 250 volts D.C., and a "continuous rating" life of more than 10,000 hours. A valve of this type is more economical in operating power than a relay, and time delays are very much shorter. Moreover, it gives a visual indication of the correct functioning of the circuit, "chatter" or sparking at contacts is eliminated, and no maintenance is required.

The CCT6 is specially designed for sequential switching circuits in which the voltage output from one valve is used to operate the next. Its dynamic sensitivity is high enough to ensure effective operation within 100$\mu$ sec. when a pulse of 110 volts is applied to the trigger through a 0·47 megohm load resistor. The valve has a B7G-type base with flying leads, and a glass envelope.

Detail improvements continue to be made in miniature type receiving valves which will make them more suitable for use at Band III television frequencies.

**SEMICONDUCTORS.**

Point contact germanium diodes are now widely used in sound and vision detector circuits and interference suppression circuits in television receivers. It has also been shown that they can be used in the " flywheel " synchronisation circuits of fringe area receivers.

A circuit likely to be widely used in frequency modulated broadcast receivers is the ratio detector ; the small size of point contact diodes, and the absence of heater wires, are decided advantages where this circuit is concerned, and it has been established that type GEX 34 diodes are particularly suitable.

The study of the factors which limit the performance of point contact diodes in high-speed pulse applications has continued, and useful information has been obtained.

Among recent developments is a high-frequency point contact triode. This has an emitter-collector spacing of 0·0008 in., compared with the 0·003 in. of the earlier type GET I, which results in an increase of cut-off frequency from about 300 kc/s to over 10 Mc/s. The device is particularly useful as a pulse amplifier ; pulses as narrow as 0·3$\mu$ sec. can be handled satisfactorily.

A *p-n-p* junction triode has been designed for low frequency, low power amplifying purposes. As the characteristics of this type of device are very sensitive to the presence of water vapour, the envelope must be hermetically sealed. This is achieved by the use of a cold welded copper can, the leads being brought out through glass-to-metal seals. A very high efficiency is obtained by this type of amplifier ; for example, in a Class B push-pull amplifier which gives 0·25 watt output at low distortion, the dissipation in each transistor is less than 50 mW.

The envelope of the *p-n* junction germanium diode shown in fig. 108 is also made of copper, sealed by cold welding. In low voltage battery charging circuits, a pair of diodes used in a bi-phase circuit can handle rectified currents of 10 amp. when simple convection cooling fins are attached to the diode. A feature of their performance is the very high rectification efficiency, values exceeding 90 per cent. being obtainable.

*Fig. 108.—Germanium p-n junction diode.*

# Research

## INTRODUCTORY.

This section deals with various phases of the work, accomplished or in progress in the Research Laboratories during the year, which are not referred to elsewhere in this series of articles.

## ILLUMINATION.

### HIGH BRIGHTNESS PHOTOMETRY.

The view was expressed earlier* that the eye may become more sensitive to light at the blue green end of the spectrum as the luminance is increased, just as the well-known Purkinje effect holds at low luminances. This view has now been substantiated by further research using a high-brightness photometer specially built for these experiments. The apparatus enables luminances of up to 50 cd/in$^2$ to be compared from sources of different colours.

### INTERIOR LIGHTING.

Illumination research, particularly the work on modelling, adaptation and emphasis, has now reached a point where an entirely new approach to the problems has been devised.† This approach has put the functions of the architect or aesthetic designer and of the illuminating engineer in their proper perspective. Called " Designed Appearance Lighting ", this new technique of calculation starts with the architect's conception of the appearance he desires, and makes it possible to plan on paper and without experiment the lighting that will produce this appearance. Besides putting the illuminating engineering part of the scheme on a sound basis, this technique provides a most satisfactory point of contact between architect and illuminating engineer.

The new method is already being used in practice, the first applications being to interiors of architectural merit and well-defined purpose, such as churches.

## DETERMINATION OF CARBON IN METALS.

During the last few years, iron and steels of very low carbon content have become increasingly important in industrial applications. The development of 4 per cent. silicon iron used for electrical purposes has pointed to the need for an alloy of carbon content 0·05 per cent. or less. Pure iron with a very low carbon content (less than 0·01 per cent.) has particularly interesting magnetic properties, and some of the special rustless steels have carbon contents ranging from about 0·1 per cent. down to as low as 0·02 per cent. When determining the carbon content of these materials, therefore, the third decimal place is becoming significant.

Two techniques have been in fairly common use for the determination of these very low carbon contents. In one of these, the carbon dioxide produced by burning the sample is absorbed and weighed in the usual way, but extra accuracy is gained by using a much larger sample than the normal 1 or 2 grams. Such large samples are not often available in research investigations. In the other, " low pressure ", method, the carbon dioxide produced from the combustion of a small sample is condensed in a liquid oxygen trap and then expanded into a vessel where its pressure can be measured ; this method is more complicated and less convenient for occasional use.

A third method, which involves the conductimetric determination of the carbon dioxide produced in the combustion of a small sample, has recently been developed at the Research Laboratories. The cylindrical conductivity cell, made of " Perspex ", has been specially designed to provide a long helical gas passage in the outer portion, with the electrode chamber in the centre. As the oxygen, containing a trace of carbon dioxide from the combustion, bubbles through the solution of barium or sodium hydroxide in the cell, the change in the conductivity of the solution is measured by a bridge arrangement. The method has now been refined to such a degree that the carbon content can be measured to four places of decimals on a 1 gram sample.

## MAGNETIC SWITCHING ELEMENTS.

Work has been proceeding on a new magnetic device for storing and handling information in electronic computing and automatic telephone exchange type equipments. Magnetic devices have advantages in that they prevent intermittent faults, require no maintenance and have no shelf-life deterioration.

Using the effect known as ferroresonance, it is possible to provide a simple bi-stable element for storage purposes. A saturable reactor is connected in a resonant L-C circuit supplied from a high frequency source. In the normal non-resonant condition, the inductor carries little current but by pulsing may be switched to another stable resonant condition with high current and a large output voltage. High permeability magnetic cores are used to provide inductances which may change by a factor of five to one from the normal low current to the saturated state (fig. 109). If this saturation inductance is arranged to resonate with the circuit capacitance at the supply frequency, resonance will be maintained when the heavy current state is reached. Additional trigger windings are used to saturate the core of the inductor temporarily, and a single current pulse in these windings can then cause a large output voltage to appear across the inductor itself.

Research into the requirements for the inductor itself is essential to ensure the reliability of the circuits in which it is used. To obtain the required efficient resonant circuits, components must have high Q and so low-loss magnetic core materials must be used. Inconsistencies in permeability and losses of these materials have been reduced by careful selection and

* *G.E.C. Journal*, Vol. XX, No. 3, July, 1953, pp. 184-7.
*G.E.C. Journal*, Vol. XXI, No. 1, January, 1954, p. 60.

† "A New Approach to Artificial Lighting," by J. M. WALDRAM, *G.E.C. Journal*, Vol. XXI, No. 4, October, 1954.

heat-treatment. The construction of the experimental ferrestors has been kept as simple as possible, with all windings enclosed in resin on a single core about 1¼ in. long.

Typical ferroresonant circuits of the type shown in fig. 110 can be used as basic " building bricks " for logical circuits, and counting chains, registers and computing circuits can be built from them.

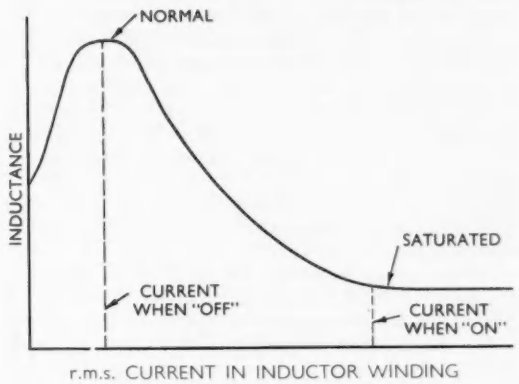



*Fig. 109.—Graph showing the variation of inductance with current of a " Ferrestor ".*

Supply frequencies of the order of 1 Mc/s can give counting rates of over 100,000 counts/second. These ferroresonant units are therefore useful for pulse operations in a frequency range intermediate between those of the cold cathode tube and of the hard valve or the transistor. Future applications may well include small telephone exchanges, compact computing and telemetering equipment.

that of X-ray diffraction has recently been demonstrated at the Research Laboratories. This combination of optical and X-ray techniques has been used successfully to analyse complex mineral mixtures, and also allows very minute amounts, even a single fragment, of one component to be separated and positively identified. This combined approach may well have many other applications outside the field of mineral dressing.

### Phosphors Containing Uranium.

Since crystal structure is an important factor in determining the luminescent behaviour of a substance, X-ray analysis is continually being used in the research into, and development of, phosphors. It is well known that uranium promotes fluorescence in a number of substances. The effect of adding controlled amounts of this element to calcium oxide was studied by X-ray techniques and it was found that new and unexpected compounds were formed under certain conditions. With a composition of the type $Ca_3UO_6$, these compounds have the same crystal structure as alkaline earth tungstates of the $R_3WO_6$ type and fluorides of the cryolite $Na_3AlF_6$ type. The identification of the $Ca_3UO_6$ uranate compounds suggested that solid solutions with $R_3WO_6$ tungstates should be readily formed, and this was confirmed by experiment. A clearer understanding has thus been achieved of the behaviour of uranium-activated tungstates, the luminescent properties of which have been known for many years.

### Magnetic Materials.

X-ray analysis plays a prominent rôle in research on magnetic materials. Effectiveness of alloy formation, composition, strain condition and crystal growth are all factors that influence the magnetic properties.

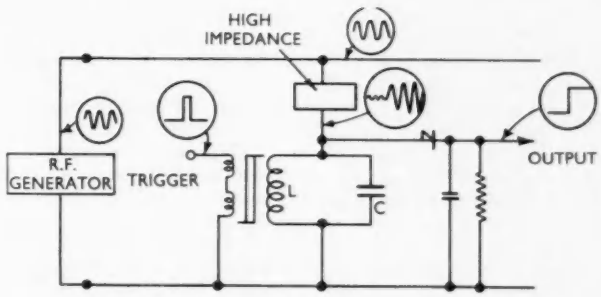



*Fig 110.—Circuit diagram of a typical ferroresonant circuit.*

## X-RAY INVESTIGATING TECHNIQUES.

### Analysis of Minerals.

Modern trends in mineral dressing are placing increasing emphasis on unusual and complex mixtures of minerals. This has added to the difficulty of identifying the components, and the classical methods of the petrological microscope or the techniques of X-ray diffraction analysis may prove inadequate. The value of combining the use of the polarising microscope with

Work of a fundamental character on the structure changes in ferromagnetic and antiferromagnetic compounds has shown that all simple monoxides containing magnetic atoms show anomalous structural deformations at particular, though different, temperatures. Such deformations have been shown to be linked with the interactions arising when thermal contraction brings the magnetic atoms within a critical distance of one another.

Investigations have also been made on certain manganese compounds with magnetic properties. X-ray diffraction instruments, capable of following changes in atomic spacing with change of temperature, have been used to measure, for example, the thermal expansion of the crystal lattice in the compound MnBi. If the lattice parameters are plotted against temperature (fig. 111), the curves show sharp discontinuities at about 320 deg. C. This is exactly the temperature at which the ferromagnetism of MnBi disappears.

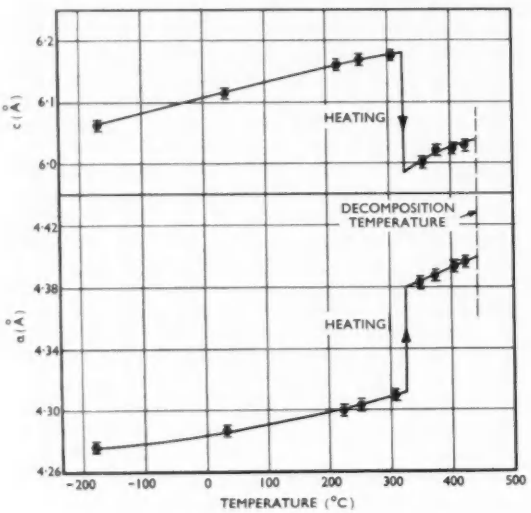



*Fig. 111.—Curves showing variations with temperature of structure-cell dimensions of MnBi.*

## COLD CATHODE TUBE CIRCUIT DESIGN.

During the development of the CCT6 cold cathode triode (see page 61) it was realised that, for full advantage to be taken of the substantial improvement in the operating life of the valve, a new order of reliability was also required in the accompanying circuit arrangement. Most circuits for such devices have hitherto been operated by means of a ' pulse + bias ' arrangement. In this technique, the triode is struck by a voltage pulse from one source, superimposed upon a steady voltage bias from another. Either of these must not be sufficiently large in amplitude to strike the tube, but every triode must fire when the two potentials are applied coincidentally. The circuit is then such that either a pulse or a bias can be derived from a tube on striking.

Good results were obtained initially in this way but a detailed analysis showed that it is difficult to achieve an economic design which can operate over the most adverse limits allowed for each of the components. Further, complete theoretical calculation of the circuit limits cannot be made, so that considerable laboratory experience is needed for each minor variation in design. When the detailed characteristics required from the CCT6 were being stipulated, it was considered desirable for the tube to provide a sufficiently large output signal on striking for other tubes to be fired directly from it. In order to achieve this over the extreme ranges of component tolerances, the minimum output potential from the tube must be about 30 volts higher than the maximum striking voltage allowed for during tube life. This requirement has been fully met by the CCT6. Also, one tube can now be fired by the coincident signals from two others, using a rectifier gating network. Applying a " d.c." signal to the trigger, rather than a short pulse, provides another advantage in that the firing time of the tube becomes far less important.

These new tube features have enabled the circuits used to be broken down into a few basic " building bricks ", which will operate over a very wide range of tolerances in component values. The design limits of these " bricks " are easily calculated so that a theoretical analysis becomes possible of the ways in which they can be combined. The " d.c." operating technique has been applied to the full range of cold cathode tube circuits, including those for counting, storing and gating. Simple and reliable interconnections between the new circuits and standard telephone relay apparatus have also been designed. The equipments using the CCT6 with the new circuit technique include register-translators enabling telephone subscribers to dial calls over longer distances, continuously operated multichannel telemetering systems for power network control, and frequency deviation display units for crystal oscillators.

## SEMICONDUCTORS.

The search for new useful semiconductors involves careful and extensive physical measurements in order to deduce the parameters which define the semiconducting properties of the materials. Investigations on the Hall effect, electrical conductivity and infra-red transmission have been carried out from liquid air temperatures up to several hundred degrees Centigrade. Even these measurements do not always allow an unequivocal evaluation of some of the parameters required. A study is therefore being made at the Research Laboratories of such quantities as the change of resistance in a magnetic field.

The results of these measurements, together with a study of the physics underlying semiconductor devices, provided the required information regarding the particular applications for which each semiconducting material is suitable. While the chief interest in semiconductors has so far arisen from their use in electronic devices (see page 61), other uses can also be obtained. One example of quite a different application of semiconducting materials is concerned with their thermoelectric properties.

Thermoelectric effects are well known in metals ; in fact, Peltier discovered 120 years ago that a junction of two dissimilar metals is cooled or heated when an electric current is passed across it. The magnitude of

the effect is, however, very small if conventional metals are used. Some semiconductors show a far more favourable combination of properties, and theoretical considerations indicated that materials of high mean atomic weight would repay investigation as possible thermoelectric materials. The new semiconductor bismuth telluride was accordingly prepared in the Research Laboratories. When a current is passed across the junction between *n*- and *p*-types of this material, a temperature difference of 37 deg. C. can be produced. If one junction is maintained at 12 deg. C., the other will then reach a temperature of −25 deg. C. Work on other materials is now proceeding with a view to obtaining even greater effects.

The same criteria used to choose semiconducting materials for their cooling effect apply for selecting those which will give the most efficient conversion of heat into electric power. If waste heat, such as that from water or low pressure steam, is used, the upper temperature would be rather less than 100 deg. C. Under these conditions, even bismuth telluride would convert the heat into electricity at no more than 2 per cent. efficiency, on account of the small temperature difference. Nevertheless, the saving of energy might well compensate for the initial cost of installing a thermoelectric generator, and there would probably be no further maintenance costs.

## THERMIONIC VALVES.

### FUNDAMENTAL RESEARCH.

The successful manufacture of thermionic valves involves as complete a knowledge as possible of the various effects occurring inside these devices. Since there are many such phenomena, all taking place simultaneously, each effect must be studied separately in order to assess its contribution to the whole art of valve-making. Work in this field has been mentioned in previous Progress Articles,* and the Research Laboratories on behalf of the M.-O. Valve Co. Ltd., have continued their programmes of fundamental research on these lines.

One problem that has recently received much attention is concerned with cathode poisoning and its causes. This occurs when the emission of electrons by the oxide-coated cathode starts to decrease, an effect which is possibly due to damage of the cathode by atoms and ions. Since the vacuum in the valve is as perfect as possible, these are most likely to have been released from other electrodes by electron bombardment. To test this theory, thin films of various compounds were bombarded with slow electrons and the actual process involved in their decomposition was investigated, together with the magnitude of this effect. The minimum energy of the electron stream needed to produce decomposition was measured for a variety of materials of the type which may be encountered on valve electrodes. For example, barium oxide of a thickness $10^{-6}$—$10^{-5}$ cm. shows instability of emission when the electron energy reaches 4 eV. This is characteristic of the arrival at the cathode of oxygen ions from the anode, to which barium oxide had previously "wandered" from the cathode. It is the decomposition of this oxide under electron bombardment which releases the oxygen atoms. The decomposition thresholds for a number of different compounds are given in Table 1.

TABLE 1.

DECOMPOSITION THRESHOLDS.

| | First Threshold for Decomposition. |
|---|---|
| NaCl | 4·5 volts |
| KCl | 4·0 volts |
| KI | 2·5 volts |
| $BaCl_2$ | 5·0 volts |
| $BaSO_4$ | 7·0 volts |
| FeO | 5·5 volts |
| CuO | 2·0 volts |
| $MoO_3$ | 7·5 volts |
| | 8·0 volts |
| NiO | 2·5 volts |
| $WO_2$ | 4·5 volts |
| $Ta_2O_5$ | 4·6 volts |
| $ZrO_2$ | 1·7 volts |
| BaS | 1.5 volts |
| SrS | 2·0 volts |

This shows that for a wide variety of compounds, decomposition occurs when they are bombarded with electrons of sufficient energy. In all cases, a gaseous constituent is liberated and ultimately poisons the emission of an oxide cathode. Further, the decomposition process leaves an excess of the metallic constituent near the surface of the bombarded compound. The presence of this metal, e.g. barium in the case of barium oxide films, then has the effect of lowering the secondary emission coefficient of the material.

Further work to elucidate the fundamental principles of cathode operation in valves has been concerned with a study of the influence of the physical and chemical properties of the oxide coating on the emission from the cathode.

The coatings used may consist of one oxide or a mixture of two or three oxides and all these types were studied. Oxide coatings are prepared by heating the carbonates of the metals concerned until all the carbon dioxide has been given off and only the required oxide or oxide mixture remains. It was found that the chemical method used to prepare the carbonate mixture has a considerable effect on the ultimate performance of the cathode. The chemical method affects the size of the carbonate particles and this in turn influences the rate of the decomposition and the structure of the resultant oxide layer. X-ray diffraction techniques were used to determine the average particle size of the carbonates and oxides in various coating mixtures. While it is not the crystal growth itself that is associated with improved emission from a particular coating, the increase in temperature which permits crystal growth has other effects on the crystal structure of the coating,

* *G.E.C. Journal*, Vol. XIX, No. 1, January, 1952, p. 71.
*G.E.C. Journal*, Vol. XX, No. 1, January, 1953, p. 40.

some of which do affect emission directly. It is believed that two processes may be involved, one being the removal of contaminants from the oxide and the other connected with the fact that above a certain temperature, lattice defects are readily formed by increased diffusion rates inside the crystal lattice.

LIFE TESTING.

The extensive research programmes concerned with the improvement of valve life and reliability ultimately require measurements of valve performance. It is therefore essential that the most up-to-date facilities for rapid and accurate measurements of all types of receiving valves are always available. Such measurements are continually being carried out at the Research Laboratories on behalf of the M.-O. Valve Co. Ltd., in the course of life tests of experimental valves as well as of standard valves in regular manufacture. The results of both these types of activity give information which is of great importance to fundamental research work on valve life.

The experience accumulated over 25 years of valve life testing has recently led to a design for a new test table which is eminently suitable for testing samples of valves during life test. The new equipment, shown in fig. 112, allows a far higher rate of working than do previous designs. A thorough preliminary analysis of the operations required to measure valve parameters has ensured that the new test table meets the requirements of operator and maintenance engineer. The indicating meters and controls are grouped around the operator's position so that all the meters may be easily seen, and the controls are arranged to conform with the pattern of test procedure. Particular attention has been paid to the appearance of the meter scales. All non-essential marking has been omitted and a balance of colour and brightness has been achieved which results in the pointers—the items of greatest significance—becoming the most prominent objects in the field of view.

*Fig. 112.—New test table designed and installed at the Research Laboratories for measuring the parameters of receiving valves during life test.*

The stability of the measuring instrument accuracy is obviously of great importance during extended life tests. The instrument mountings in the new test table have been designed so that the instruments can readily be calibrated together with their mounting panels and associated switching equipment. This novel feature ensures that the calibration established outside the table is identical with that encountered when in use.

# TECHNICAL LITERATURE

*A digest of recent books, articles and papers, by members of the G.E.C. and its associated companies*

## THE THERMIONIC EMISSION FROM THIN FILMS OF BARIUM AND STRONTIUM OXIDE (556).*

**By J. Woods and D. A. Wright (Research Staff of the M.-O. Valve Co. Ltd., at the G.E.C. Research Laboratories).**

*British Journal of Applied Physics, Vol. 5, pp. 47-76, February, 1954.*

The thermionic emission from thin evaporated films of barium and strontium oxide has been studied. Thin barium oxide films have a good emission following evaporation. The emission improves a little during heat treatment, and is then similar to that from a sprayed cathode coating of barium oxide. There is a maximum emission at a thickness of $10^{-5}$ cm. Strontium oxide behaves in a similar way, with a lower level of emission. If barium oxide is evaporated on strontium oxide, the best emission obtainable is as for barium oxide alone. If, however, strontium oxide is evaporated on barium oxide, heat treatment results in an emission higher than that from either barium or strontium oxide alone, and similar to that from a sprayed cathode coating of mixed barium and strontium oxide. The emission is best when the strontium oxide thickness is $10^{-5}$ cm., whether the barium oxide thickness is of this order or greater.

## THE POLARISING MICROSCOPE IN THE X-RAY ANALYSIS OF MINERALS (557).*

**By E. G. Steward (G.E.C. Research Laboratories).**

*The Analyst, Vol. 79, No. 936, pp. 173-174, March, 1954.*

In chemical indentification problems the various uses of the polarising microscope and of X-ray diffraction are well established. The value of a combination of the two methods is not, however, so widely appreciated. For example, the polarising microscope provides a valuable supplement and aid to X-ray techniques in investigations involving the identification of the constituents in mineral mixtures. Such mixtures are often encountered in the field of mineral dressing.

Two general types of problem occur in which the combination of microscopic and X-ray diffraction methods has proved particularly powerful.

## SOME EFFECTS OF SLOW ELECTRON BOMBARDMENT IN THERMIONIC VALVES (561).*

**By D. A. Wright (Research Staff of the M.-O. Valve Co. Ltd., at the G.E.C. Research Laboratories).**

*British Journal of Applied Physics, Vol. 5, pp. 108-111, March, 1954.*

This paper describes first the general features of the interaction between slow electronics and solids upon which they impinge. The threshold electron energies for the absorption of electrons, for the appearance of secondary emission and for decomposing the bombarded solid have been measured for a number of compounds. The values are quoted and are related to the optical absorption bands of the compounds. The effects on valve characteristics and on cathode emission are described briefly, when such compounds are present on the valve electrode surfaces.

## CONDUCTIMETRIC DETERMINATION OF CARBON IN METALS (563).*

**By J. E. Still, L. A. Dauncey and R. C. Chirnside (G.E.C. Research Laboratories).**

*The Analyst, Vol. 79, No. 934, pp. 4-17, January, 1954.*

The metal sample is burnt in oxygen in a normal combustion tube and resistance furnace. The carbon dioxide evolved is absorbed in sodium hydroxide or barium hydroxide solution and measured by the change in electrical conductance of this solution.

An improved loading device allows introduction of the sample and gives a good view of the combustion process, without admission of atmospheric carbon dioxide. A conductivity cell made of "Perspex" provides for continuous circulation of the absorbing solution and for measurement of the conductance at any time without stopping the oxygen flow. Except when the highest precision is required for extremely low carbon contents, sodium hydroxide solution is preferred to barium hydroxide solution. A special conductivity bridge, ordinary 50-cycle A.C. and a vibration galvanometer give high precision of measurement over a wide range; provision is made to compensate for the capacitance of the cell. The apparatus requires the minimum of maintenance, both in preparation for a series of analyses and in use.

The method gives adequate precision and accuracy on 1-g samples of standard steels and cast irons containing from 0·03 to 3 per cent. of carbon, the only change necessary over this range being an alteration in solution concentration. A wide variety of samples of metals and alloys, weighing from 0·1 to 3-g and containing from 8 per cent. down to 0·01 per cent. or less carbon, have been analysed satisfactorily.

## STUDIES IN INTERIOR LIGHTING (565).*

**By J. M. Waldram (G.E.C. Research Laboratories).**

*Transactions of the Illuminating Engineering Society, Vol. XIX, No. 4, 1954.*

The mechanism of interior lighting has been recently discussed in a Report of a Committee of the National Illumination Committee. The present paper records studies in three aspects of interior lighting: Adaptation, Revealing of Form and Texture, and Emphasis. It is proposed that effects of adaptation should be taken into account in lighting calculations and values of apparent brightness used, for it is shown that figures of apparent brightness accord much better with experience than figures of absolute luminance, and explain anomalies which are found with absolute figures.

A new method of calculation is outlined whereby the effects of inter-reflection can be found very simply without complex theory and by means suitable for day-to-day work, so that the installation can be designed from a specification of apparent brightness distribution. The mechanism of the revealing of form and texture is discussed. Apparatus for the quantitive and systematic study of modelling and shadow are described; modelling indices and methods of portraying modelling capability of the lighting are proposed. Results in interiors of different types are given.

Emphasis is a more subtle effect than modelling and does not lend itself so well to quantitive study; it is discussed qualitatively and more briefly.

The techniques of experimental study of complete interiors are described and further general observations recorded. The effects of the factors discussed upon the lighting design for interiors are considered and possible techniques outlined. An appendix gives definitions of special terms used in the paper; a second appendix discusses techniques used, and a third describes the new method of calculation.

## MAGNETIC TRANSITIONS AND STRUCTURAL CHANGES IN HEXAGONAL MANGANESE COMPOUNDS (573).*

**By B. T. M. Willis and H. P. Rooksby (G.E.C. Research Laboratories).**

*Proceedings of the Physical Society, B, Vol. LXVII, p.* 290, 1954.

The lattice parameters of the isomorphous compounds MnAs, MnSb and MnBi have been measured over a temperature range which includes the temperatures at which certain magnetic transitions occur. Characteristic changes develop near the magnetic transition temperatures and are of two kinds : (*a*) discontinuous changes of lattice dimensions (MnAs at 40 deg. C., MnBi at 320 deg. C.), which are associated with magnetic transitions of the first order; (*b*) discontinuous changes of the temperature derivatives of the lattice parameters (MnAs at 130 deg. C., MnSb at 320 deg. C.), associated with second-order magnetic transitions. Correlation of the results on MnAs and MnSb with those obtained by Greenwald on MnTe indicates that the magnetic exchange energy for manganese atoms at a distance $r$ apart is a maximum for $r = 2{\cdot}94$ Å. The magnetic change which takes place in MnBi near 440 deg. C. is caused by decomposition of the material and is not a Curie point phenomenon.

## TRANSISTORS AND CRYSTAL DIODES.

**By B. R. Bettridge (Osram Valve and Electronics Department).**

*London Norman Price (Publishers) Ltd.*, 1954. *Price* 5*s.*

The subject of transistors and other semiconductor devices has hitherto been covered on such a level as to be comprehensible only to the specialist. This small book sets out to deal with the matter in simple terms, yet without simplifying it to the point of making it unsound. As such, it constitutes an excellent introduction for those possessing no prior knowledge of the subject.

A description is given of what semiconductors are and also an explanation of how rectification and amplification take place in both point-contact and junction devices. Their characteristics are examined, and this is followed by a consideration of circuit technique and a description of a number of practical circuits. There is a brief chapter on equivalent circuit networks and another on elementary methods of testing. The book concludes with an appendix containing brief characteristics of a selection of the better known devices on the market at the present time.

## CO-ORDINATION OF INSULATION OF HIGH VOLTAGE ELECTRICAL INSTALLATIONS.

**By J. S. Cliff (Witton Engineering Works).**

*Proc. I.E.E., Part I, Vol.* 101, *March*, 1954.

The requirements of insulation for high-voltage equipment cover a number of factors, some of which affect the long-term life of the insulation and others which affect the performance only under abnormal stresses of short duration. The paper considers the system characteristics which affect the choice of insulation and assesses the various over-voltages which may be imposed upon the apparatus. The different forms of over-voltage protective apparatus available are considered and finally guidance is offered on the selection of insulation for the usual applications covered by national and international specifications.

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